Stock assessment models at Alaska Fisheries Science Center Theme I – Part II

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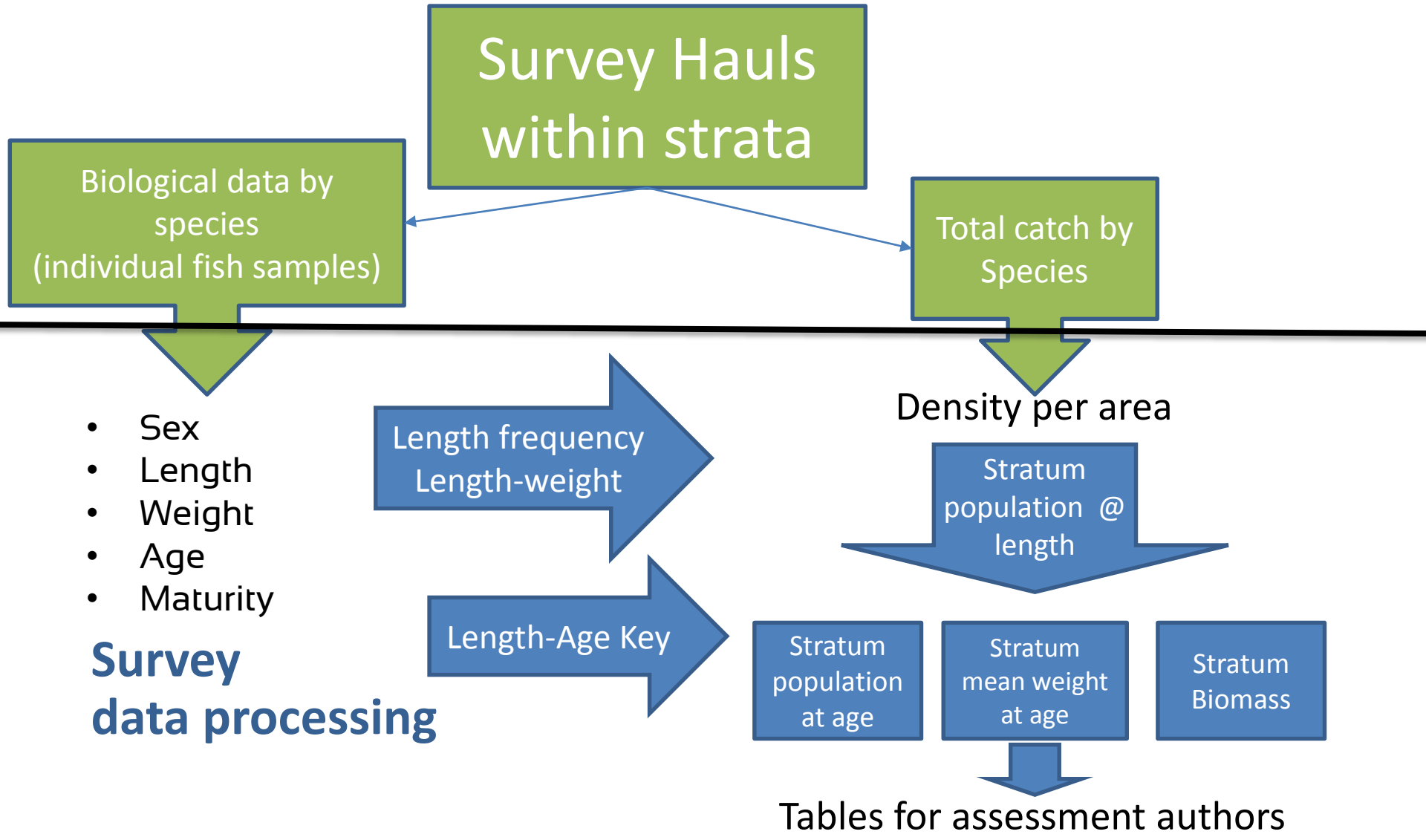
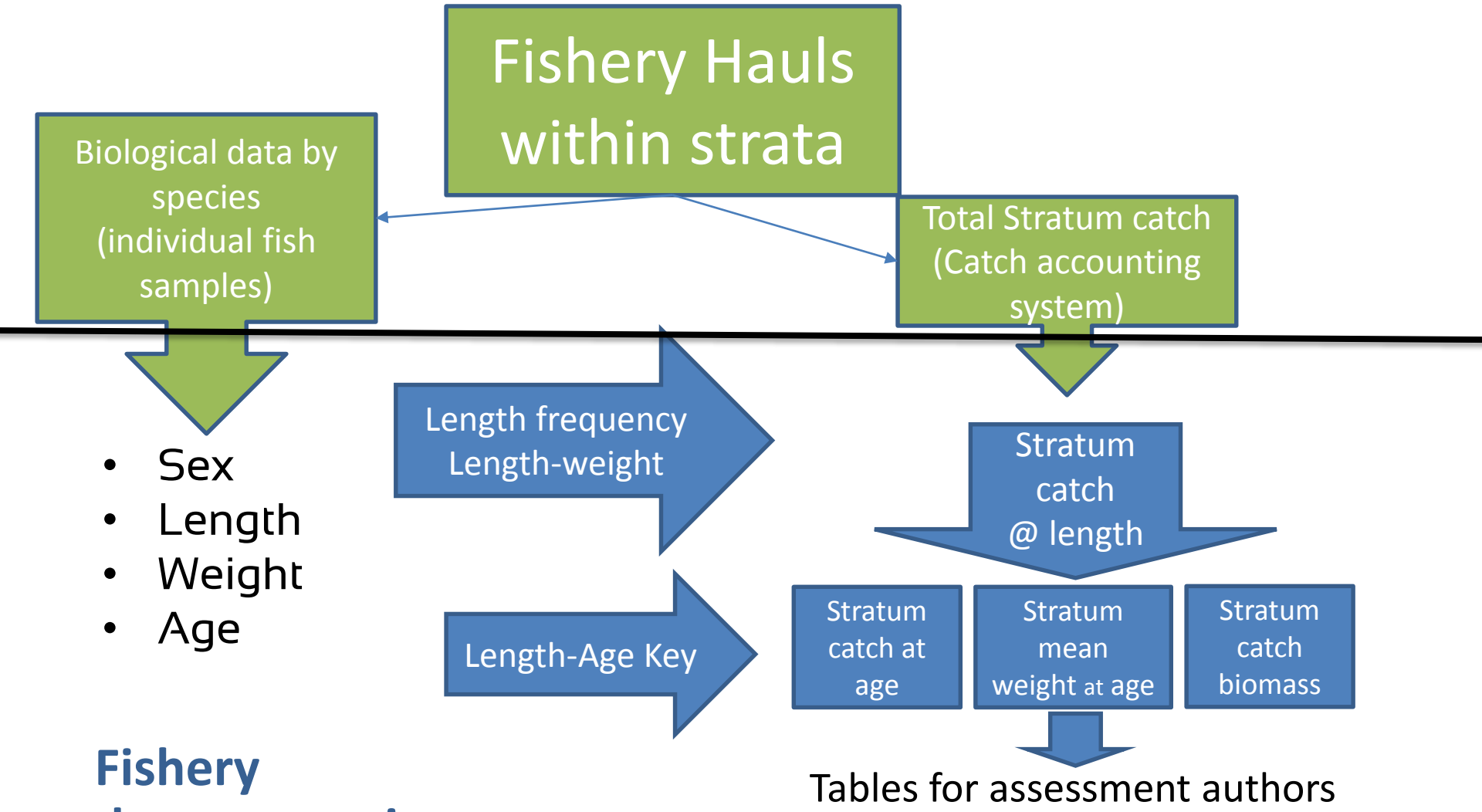
How data are prepared (generally) for assessments

Survey Data collection



Survey data processing

Fishery data collection



Fishery data processing

General assessment philosophy

- Separate model dynamics from data
  - Apply statistical principles
  - I.e., can deal with sparse data (not intertwined)
- Use all available data
  - Integrated approach
- Evaluate critical assumptions, e.g.,
  - Natural mortality
  - Survey prior on catchability

Software

- AD Model Builder (ADMB)
  - Simplified method for developing code
    - Structured approach (data, parameters, eqn)
    - Uses automatic differentiation
  - Geared toward solving complex non-linear estimation issues
    - Statistical formalism

Modeling

- Age-structured models
  - Fundamentally numbers at age
  - Baranov catch equation
  - Survey and/or Fishery indices
  - Age and length composition
- Parameter estimation
  - Data likelihoods, priors and parameter penalties
  - Statistical weights evaluated
    - Generally use sampling error as minimum estimates

Example Basic Model Equations

$$\hat{C}_t = \sum_a w_{t,a} \hat{N}_{t,a} \frac{F_{t,a}}{Z_{t,a}} \left(1 - e^{-Z_{t,a}}\right)$$ Catch biomass

$$\hat{B}_t^{survey} = q \sum_a w_{t,a} \hat{N}_{t,a} \hat{s}_a e^{-Z_{t,a}\Delta_q}$$ Survey indices

$$\hat{B}_t^{spawning} = \sum_a w_{t,a} \hat{N}_{t,a} \phi_a e^{-Z_{t,a}\Delta_\phi}$$ SSB

Model numbers-at-age

$$N_{t,a} = \begin{cases} e^{\mu_t + \tau_t}, & a = a_0 \\ N_{t-1,a-1} e^{-Z_{t-1,a-1}}, & a_0 < a < a_+ \\ N_{t-1,a-1} e^{-Z_{t-1,a-1}} + N_{t-1,a} e^{-Z_{t-1,a}}, & a = a_+ \end{cases}$$

$$Z_{t,a} = s_{t,a} F_t + M_{t,a}$$

Stock recruitment

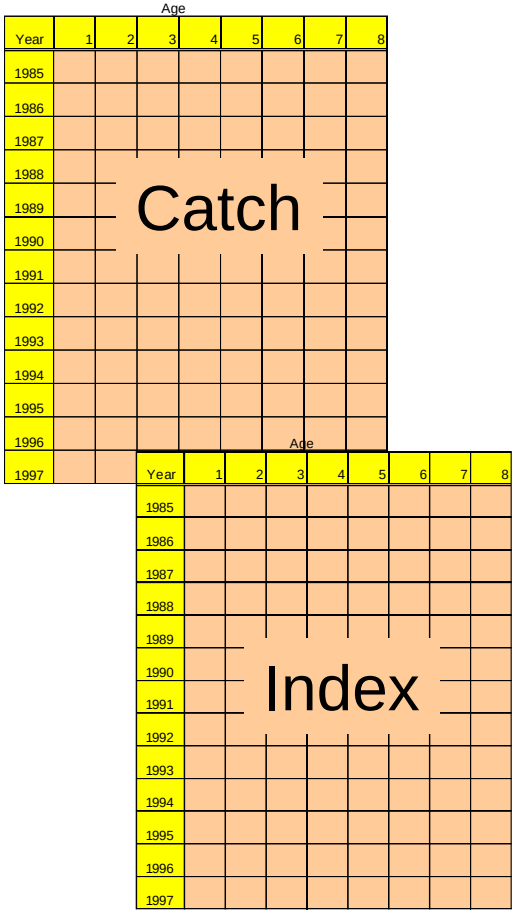
$$\hat{R}_t = f\left(\hat{S}_{t-a_R}\right) e^{\varepsilon_t} \qquad \varepsilon_t \sim N\left(0, \sigma_R^2\right)$$

	Age							
Year	1	2	3	4	5	6	7	8
1985								
1986								
1987								
1988								
1989				$N_{4,1989}$				
1990					$N_{5,1990}$			
1991								
1992								
1993								
1994								
1995								
1996								
1997								

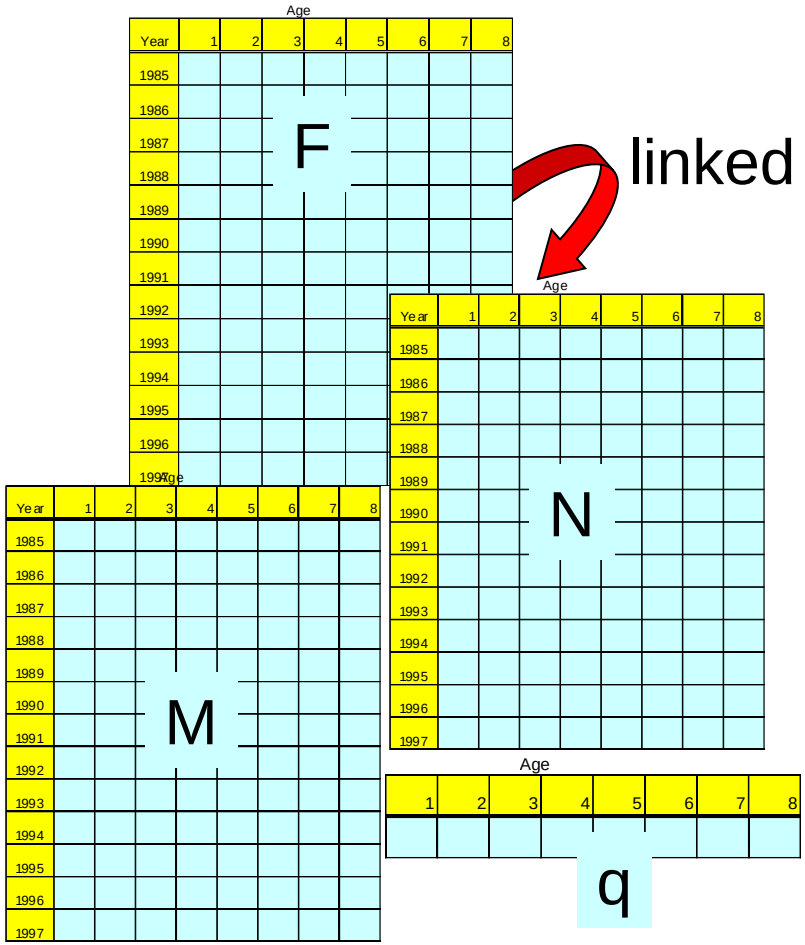
$$N_{a+1,y+1} = N_{a,y} e^{-\left(F_{a,y}+M_{a,y}\right)}$$

$$C_{a,y} = \frac{F_{a,y} N_{a,y} \left(1 - e^{-\left(F_{a,y}+M_{a,y}\right)}\right)}{\left(F_{a,y} + M_{a,y}\right)}$$

- Observed

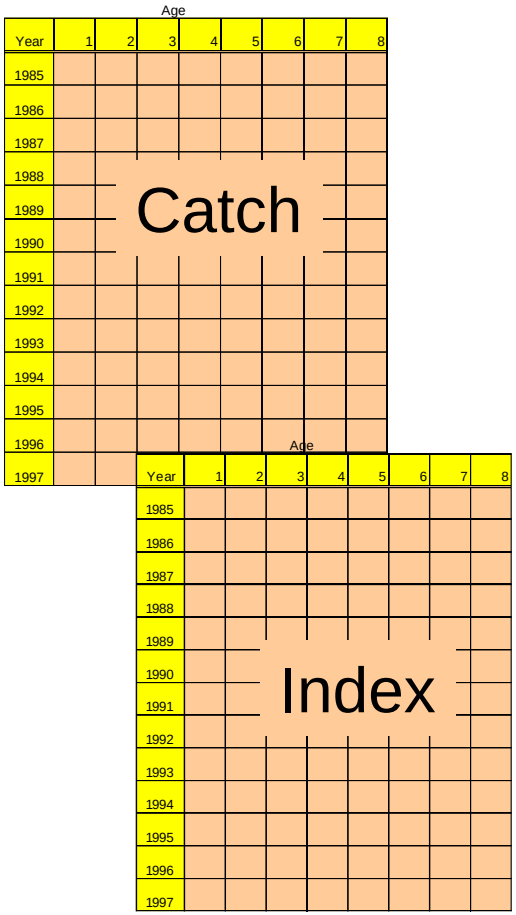


Model Parameters

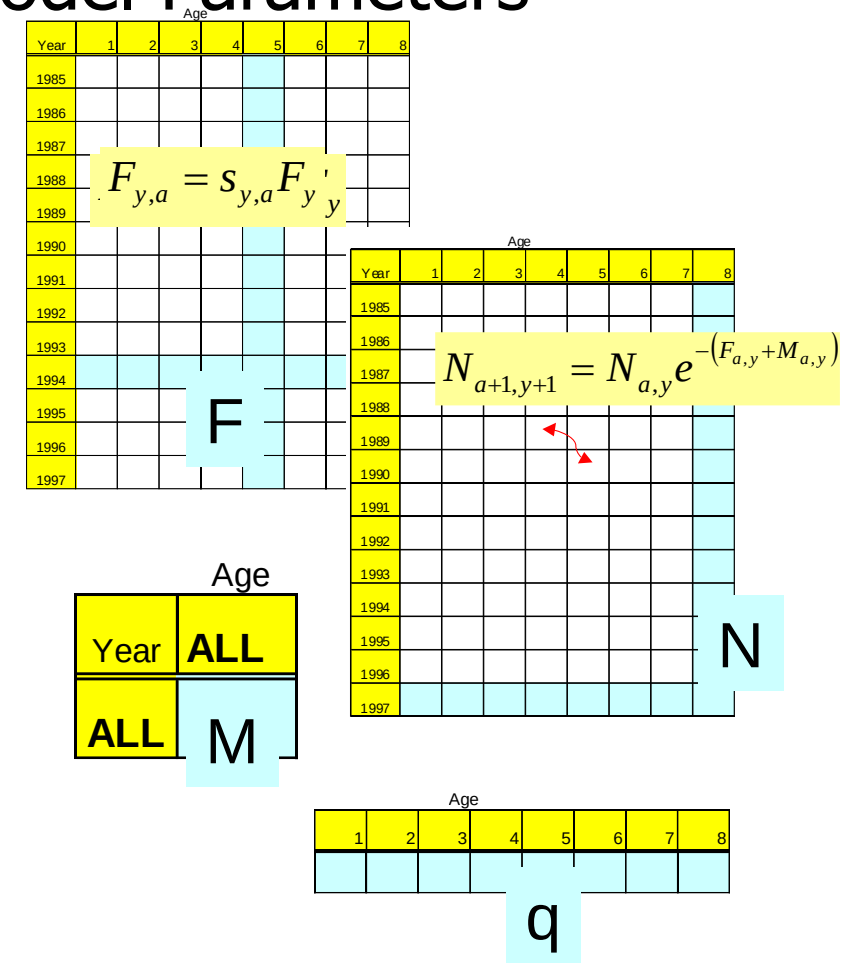


Model schematic

- Observed



Model Parameters



Likelihoods and priors

Negative log likelihoods

Log-normal (for priors and indices):

$$-\ln L \propto n\left(\ln \sigma\right) + \sum_{n} \frac{\left(Y_i - \hat{Y}_i\right)^2}{2\sigma^2}$$

Multinomial:

$$-\ln L_i \propto \sum_{i=1}^{n} N_i \sum_{j}^{J} \left(o_{i,j} + k\right) \ln\left(p_{i.j} + k\right)$$

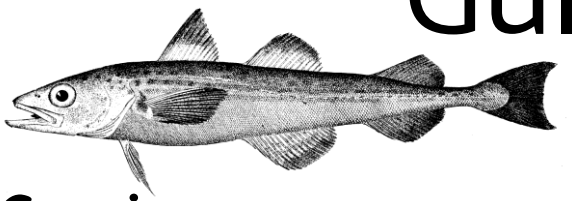
Presentations of assessments

- Brief summary of a few to display the scope of data and approaches

Species overviews
(presentation to Council/SSC)

1. 2014 ABC/Catch and recommended changes
2. Highlights
   - New data
   - Analytic approach (changes)
3. Stock status and trend
4. ABC/OFL
   - Tier history and recommendations
   - 2014, 2015 maxABC; recommended ABC

Gulf of Alaska ABC

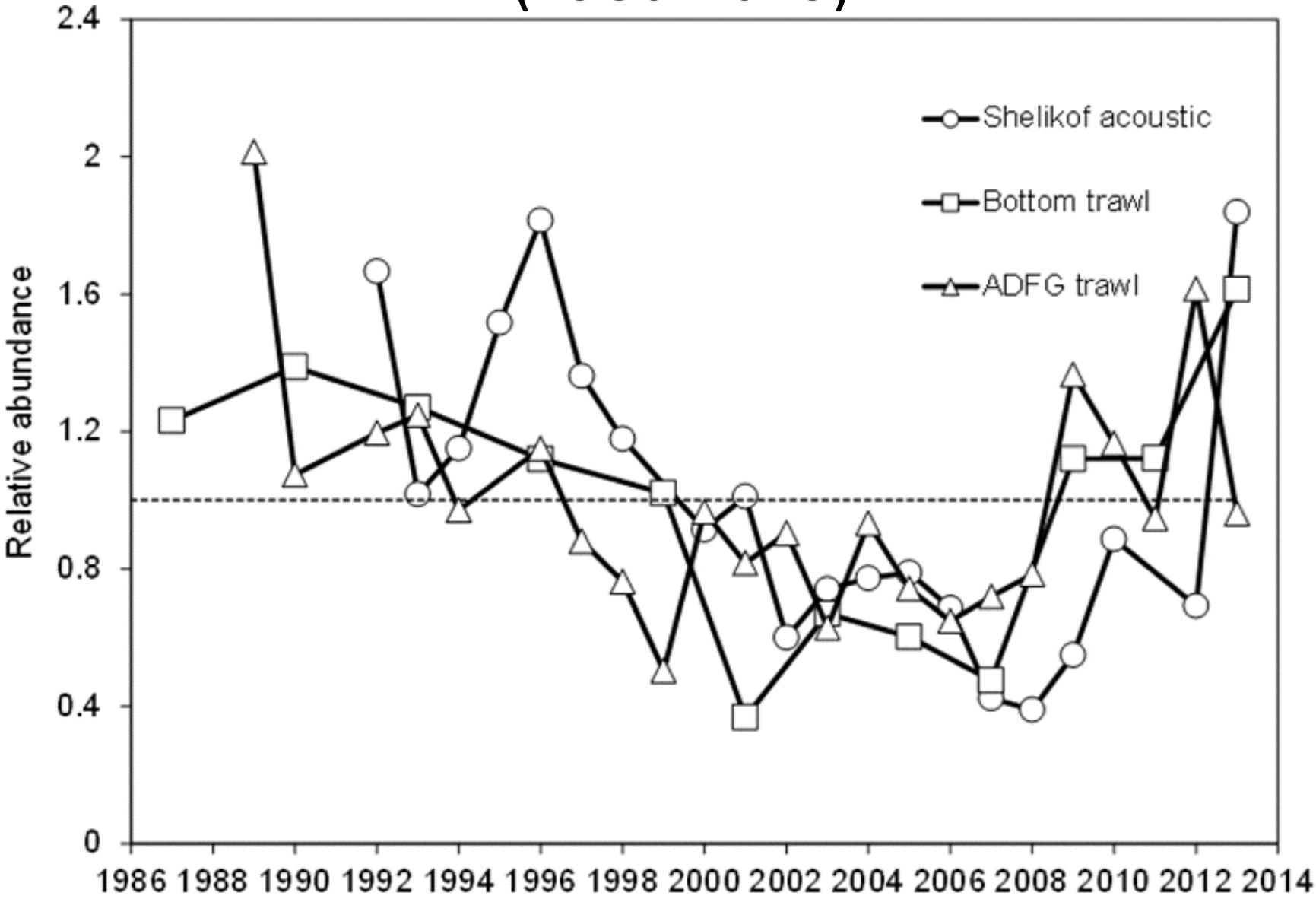


Species	2013 Catch	ABC 2013	ABC 2014	Change
Pollock	93,246	121,046	174,976	up 53,930 (45%)
Pacific Cod	46,642	80,800	88,500	up 7,700 (10%)
Sablefish	11,825	12,510	10,572	down 1,938 (15%)
Flatfish	28,619	108,908	104,849	down 4,059 (4%)
Arrowtooth flounder	2,627	210,451	195,358	down 15,093 (7%)
Rockfish	24,287	34,568	38,880	up 4,312 (12%)
Atka mackerel	1,244	4,700	4,700	same (0%)
Skates	5,590	8,422	8,627	up 205 (2%)
Other Species	4,153	14,515	14,213	down 302 (2%)
Total	218,233	595,920	640,675	up 44,755 (8%)

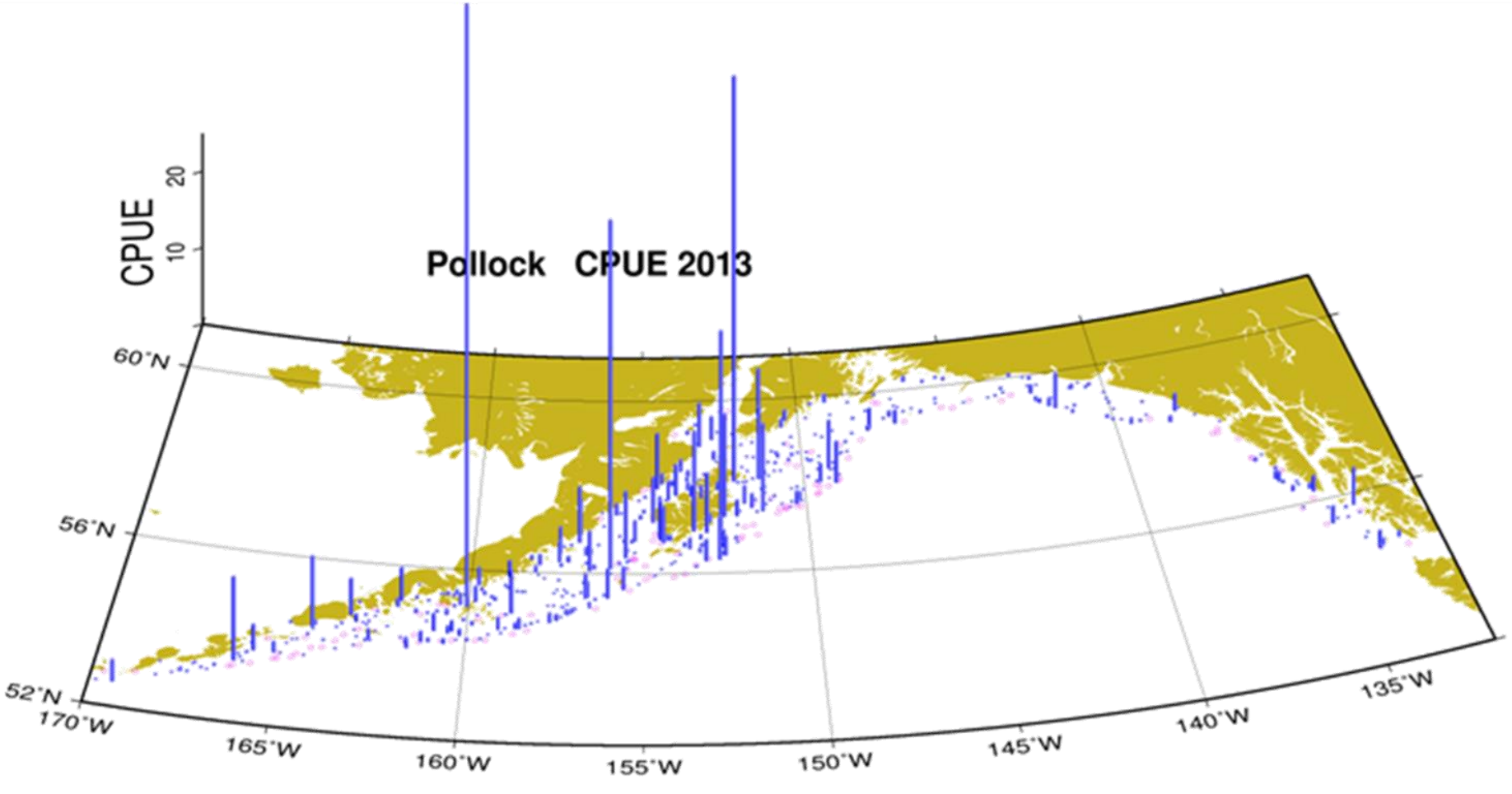
GOA pollock

Source	*Type*	*Years*
Fishery	Total catch biomass	1964-2012
Fishery	Length composition	1964-1971
Fishery	Age composition	1972-2012
Shelikof Strait acoustic	Biomass	1981-2013
Shelikof Strait acoustic	Age composition	1981-2013
NMFS bottom trawl	Area-swept biomass	1984-2013
NMFS bottom trawl	Age composition	1984-2011
NMFS bottom trawl	Length composition	2013
ADFG trawl survey	Area-swept biomass	1989-2013
ADFG survey	Age composition	2000, 2002, 2004, 2006, 2008, 2010, 2012

Relative trends in abundance indices (1986-2013)



CPUE for NMFS bottom trawl survey 2013



GOA pollock model changes

Biosonics acoustic survey period:

Removed 1992 and 1993 since produced with EK500

- Higher noise threshold

CVs for remaining estimates set equal 0.2

Removed ADFG survey length data

Increased input sample sizes ADFG survey **age** data.

4 models, 2 alternatives:

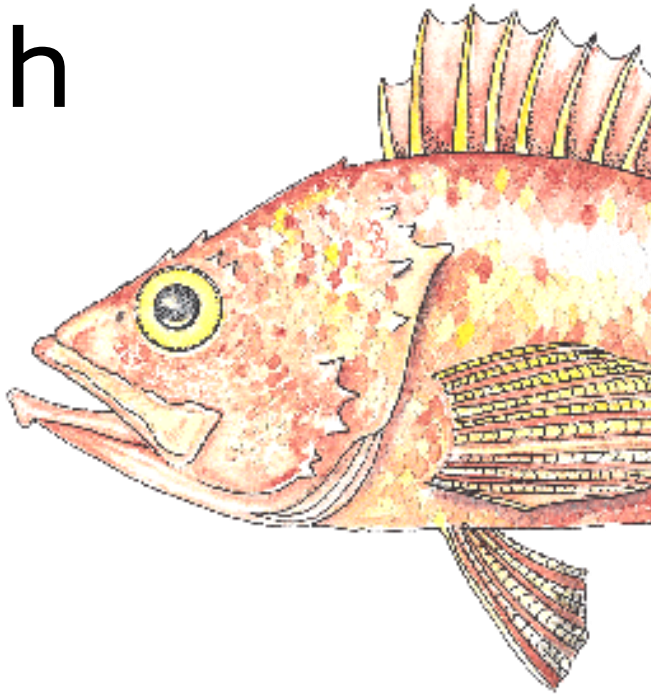
1. *Last year's model with last year's data,*
2. *Last year's model with new data (Model 0),*
3. Base model (with new data, Model 1) ,
4. Base model with 2012 year class set to average (Model 1A).

Comparison of models

GOA pollock

	Last year	*Model 0*	*Model 1*	*Model 1A*
Stock status (t)				
2014 Spawning biomass	247,699	308,465	308,541	308,135
(CV)	(10%)	(12%)	(11%)	(11%)
Depletion (B2014/B0)	33%	40%	42%	42%
$B_{40\%}$	296,519	308,975	290,460	290,460
2014 yield (000 t)				
Author's ABC	104.16	154.43	167.66	151.05
MaxABC	115.98	178.79	183.94	165.81

GOA Pacific ocean perch

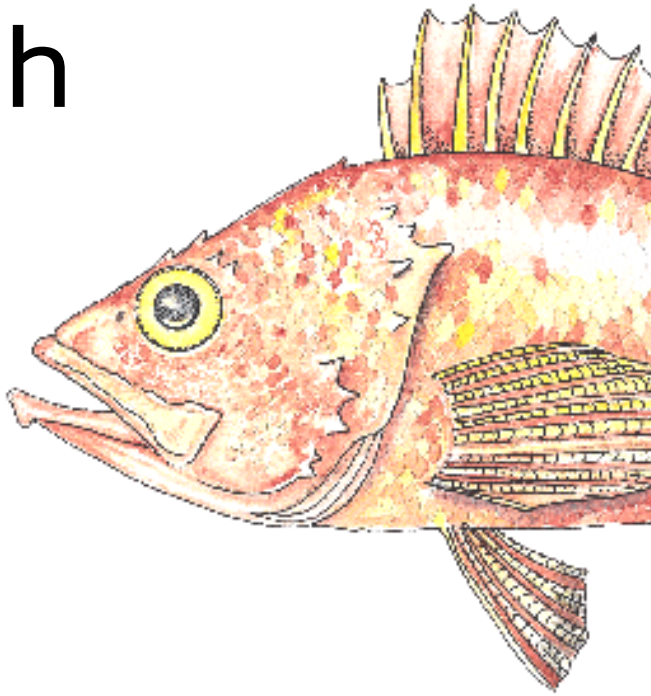


New Data

- 2013 survey biomass
- 2011 survey age compositions
- 2012 fishery age compositions

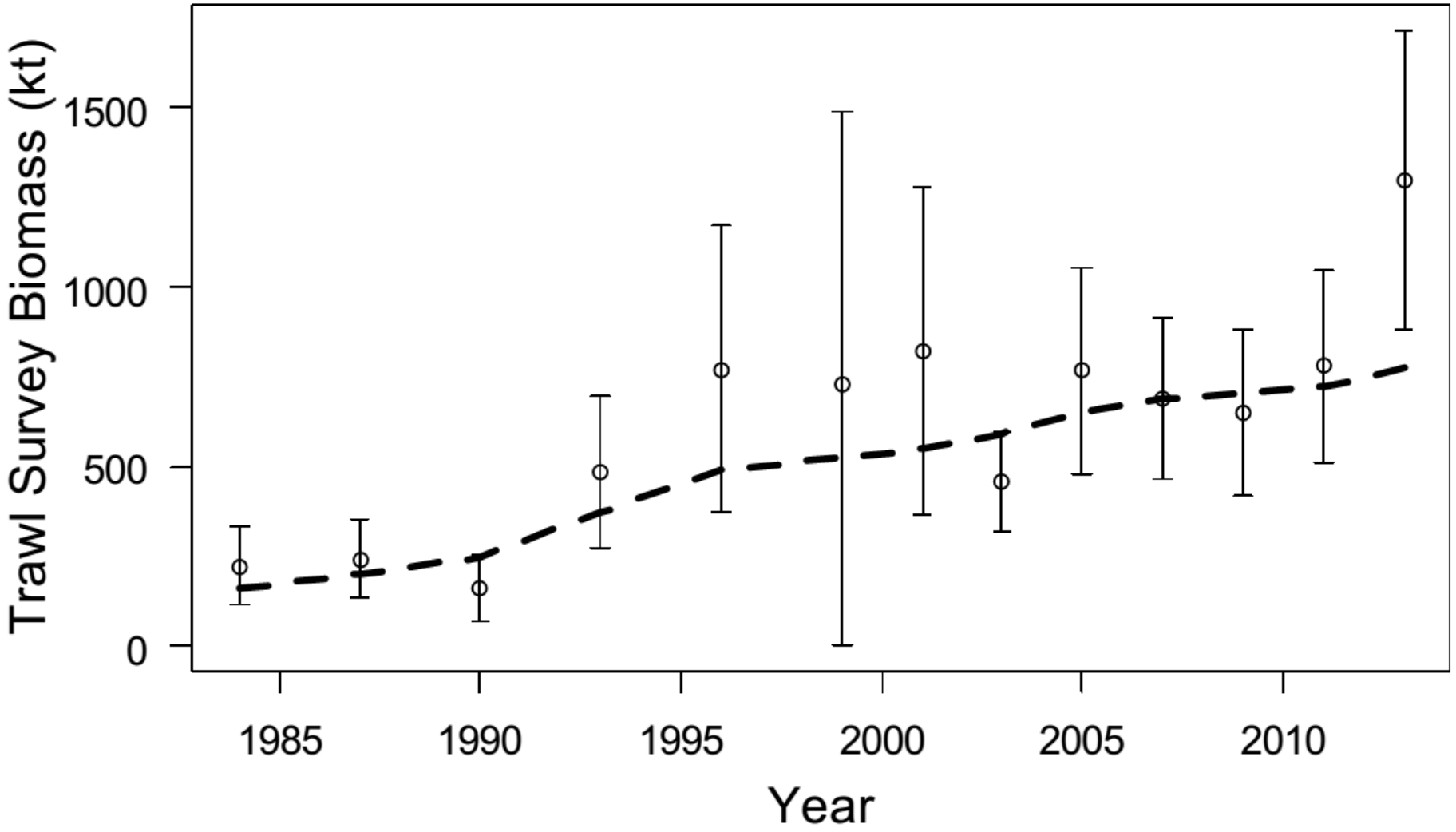
Large increase in 2013 survey biomass contributed to increase in est. recruitment of 2006 year-class with large uncertainty

GOA Pacific ocean perch

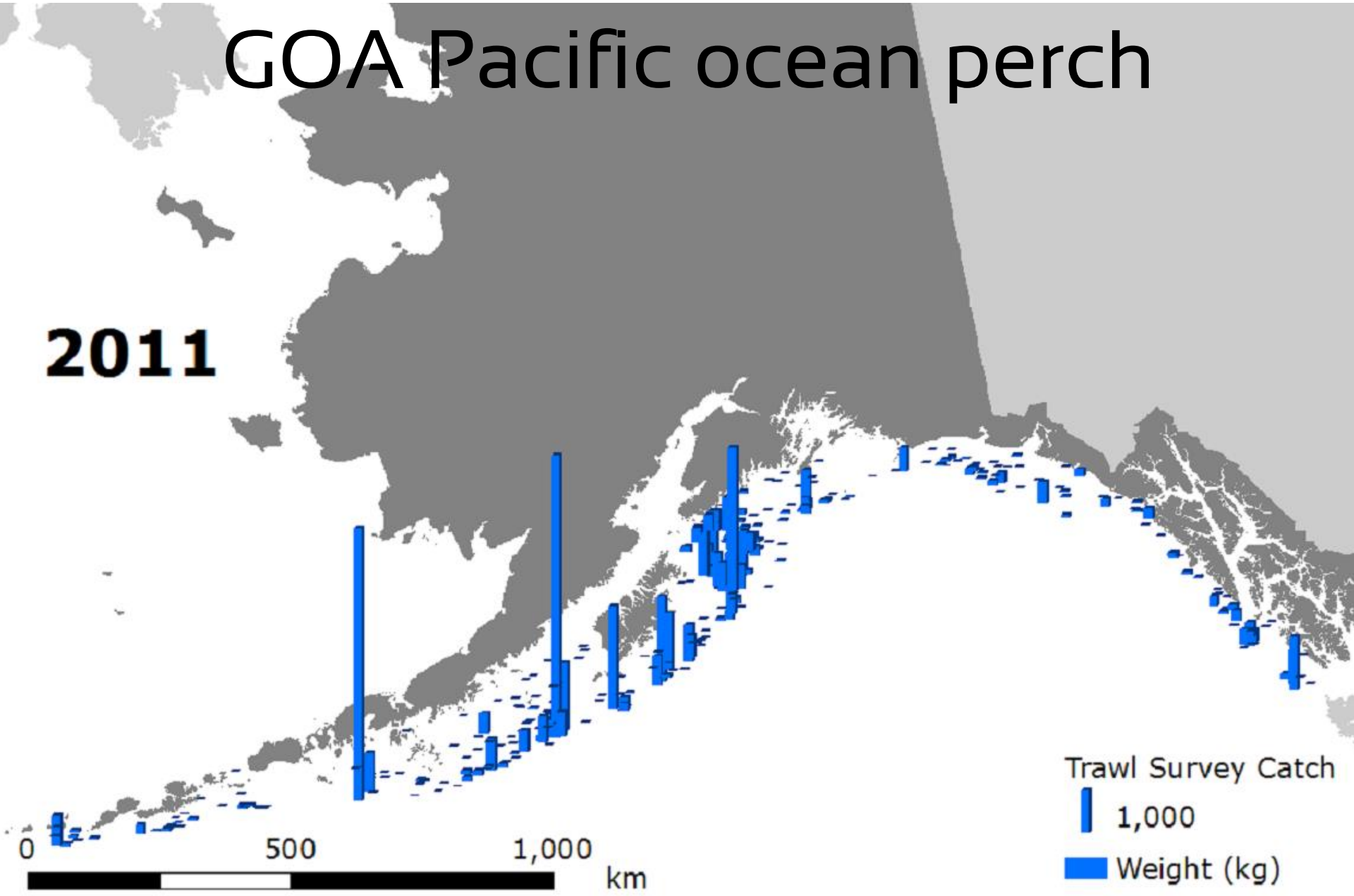


Source	Data	Years
NMFS Groundfish survey	Survey biomass	1984-1999 (triennial), 2001-2013 (biennial)
	Age Composition	1984, 1987, 1990, 1993, 1996, 1999, 2003, 2005, 2007, 2009, 2011
U.S. trawl fisheries	Catch	1961-2013
	Age Composition	1990,1998-2002, 2004, 2005, 2006, 2008, 2010
	Length Composition	1963-1977, 1991-1997

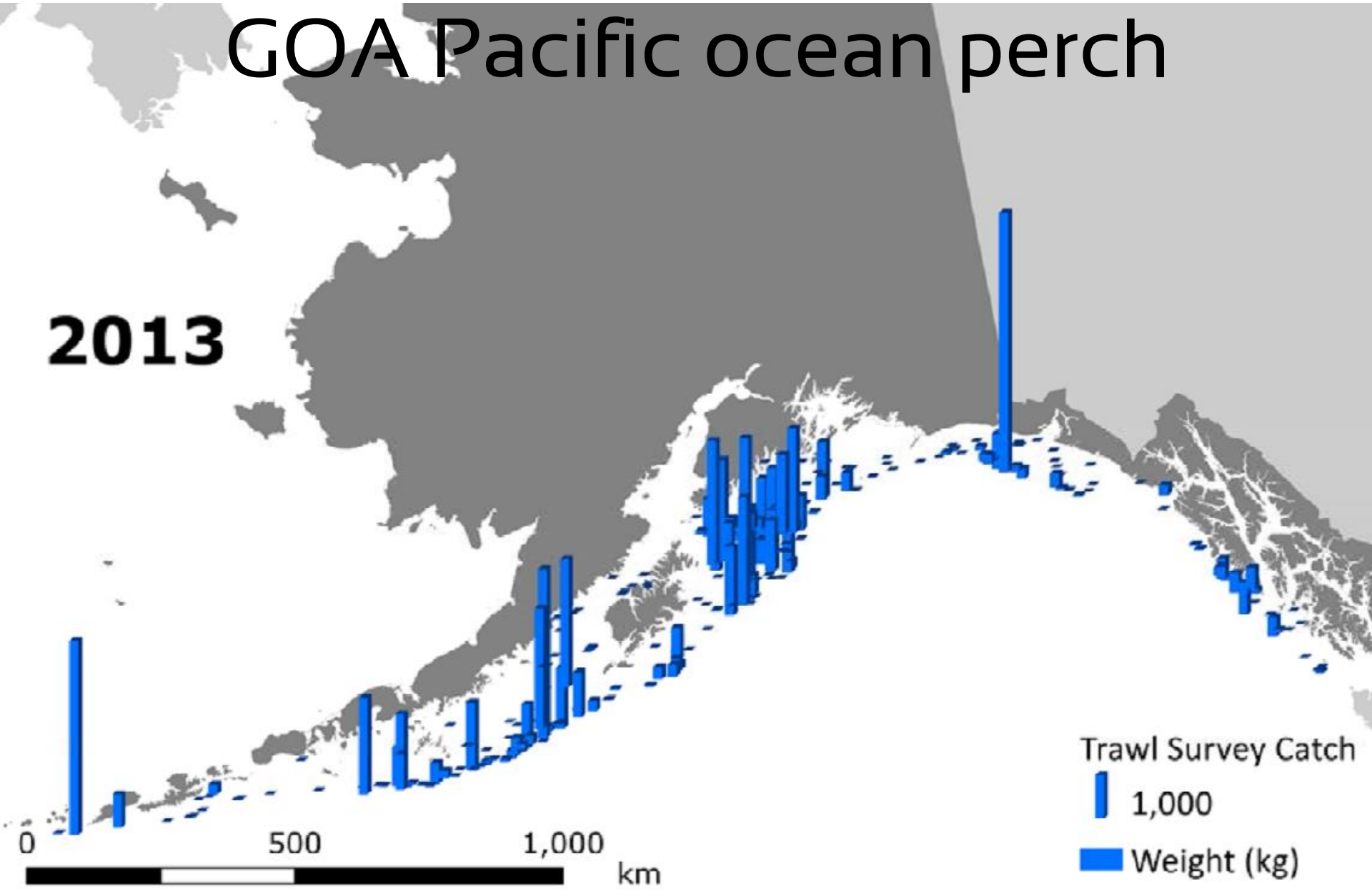
GOA POP fit to survey



GOA Pacific ocean perch

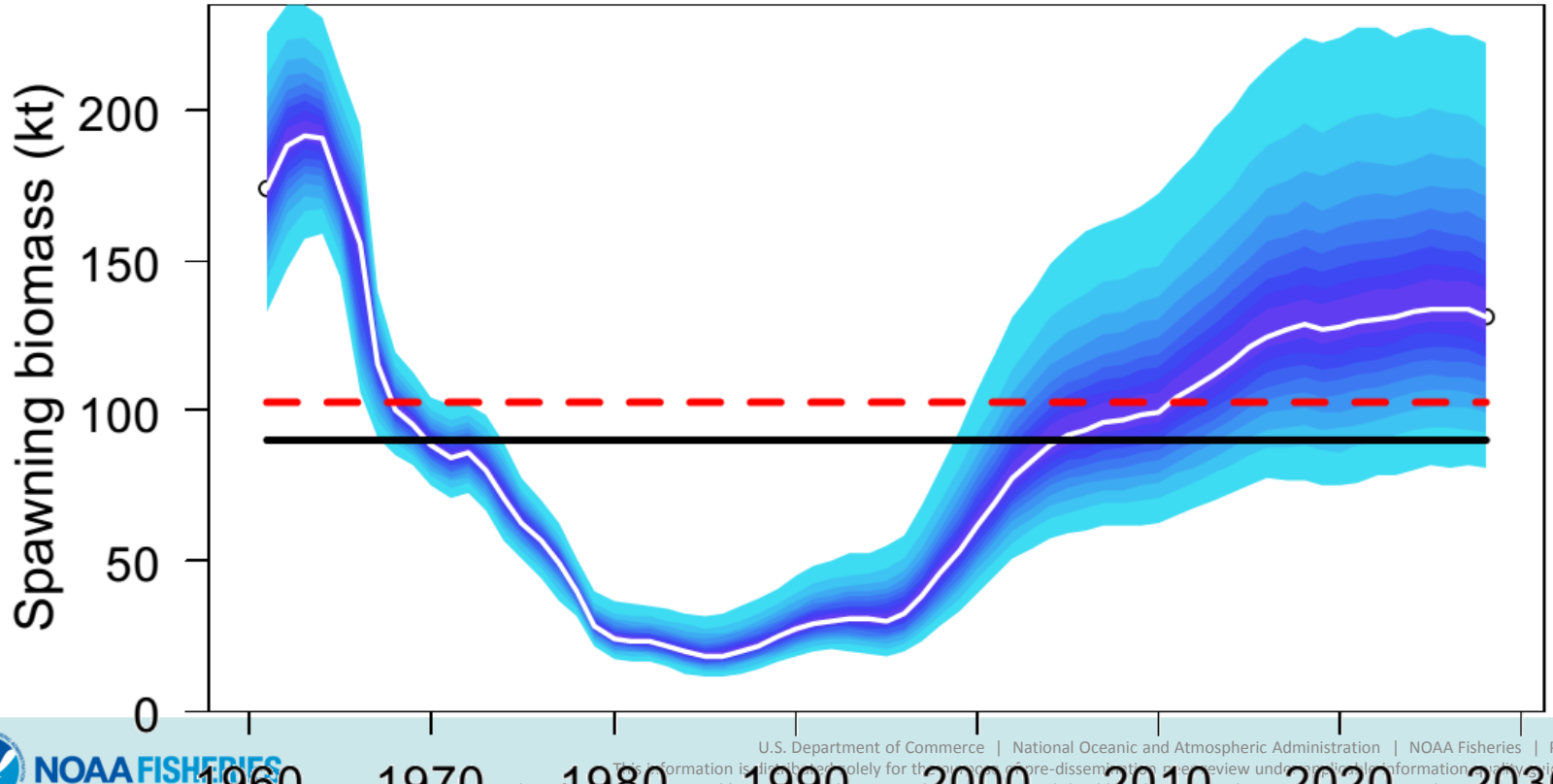


GOA Pacific ocean perch



GOA Pacific ocean perch

Pacific ocean perch	Biomass	OFL	ABC
2014	410,712	22,319	19,309
2015		22,849	19,764



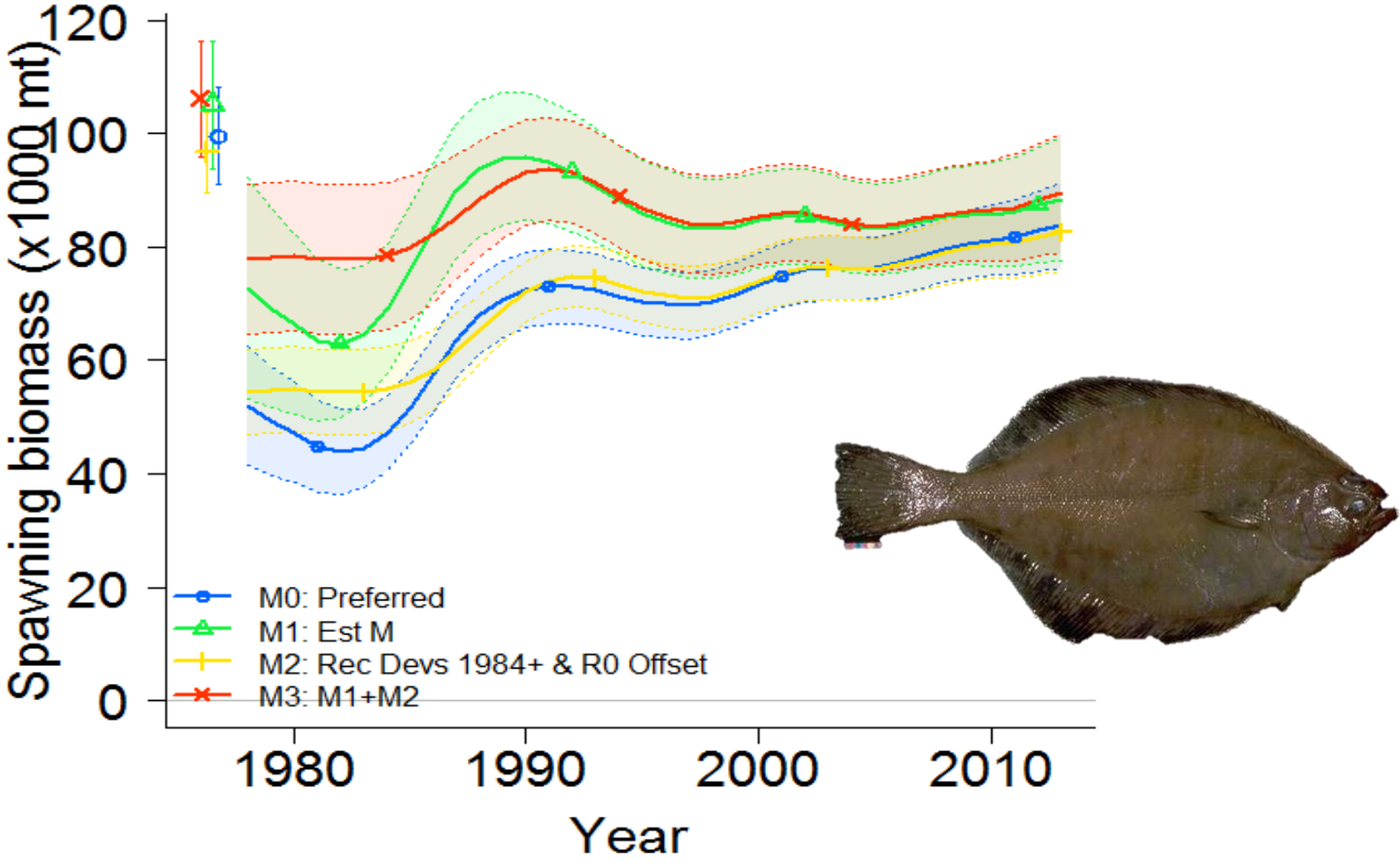
Changes in GOA flathead sole model structure

- Adapted to SS3 in 2013
- Fishery and survey selectivity curves:
  - Age-based double-normal, asymptotic
- A conditional age-at-length likelihood approach
- von-Bertlanfy growth
- Estimated variability of length at age
- Francis (2011) method of data-weighting
- Adding age determination errors
- Similar to GOA Dover sole (conversion to SS3 etc)

GOA Flathead sole data

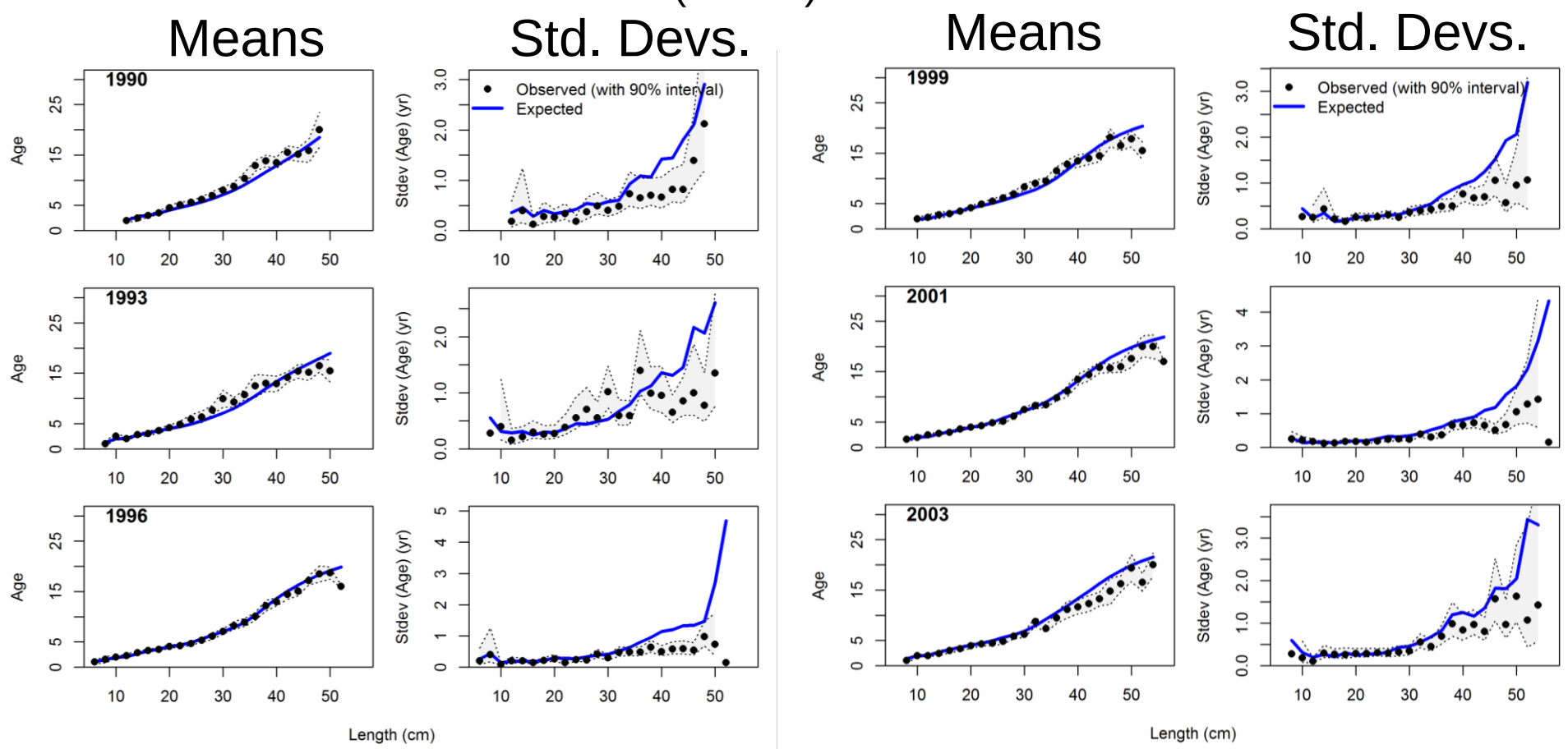
Source	Type	Years
Fishery	Catch biomass	1978-2013
Fishery	Catch length composition	1989-1999, 2001-2007, 2009-2013
Survey bottom trawl	CPUE	Triennial: 1984-1999, Biennial: 2001-2013
	Length compositions	
	Age composition, conditioned on length	

GOA flathead sole spawning stock biomass



GOA Flathead sole
Fits to conditional age-at-length data

(female)



GOA Flathead sole summary table

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2013	2014	2014	2015
M (natural mortality rate)	0.2	0.2	0.2	0.2
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	288,538	285,128	252,361	253,418
Female spawning biomass (t)				
Projected				
Upper 95% confidence interval	--		84,076	83,287
Point estimate	106,377	107,178	84,058	83,204
Lower 95% confidence interval	--		84,045	83,141
$B_{100\%}$	103,868	103,868	88,829	88,829
$B_{40\%}$	41,547	41,547	35,532	35,532
$B_{35\%}$	36,354	36,354	31,090	31,090
F_{OFL}	0.593	0.593	0.61	0.61
$maxF_{ABC}$	0.45	0.45	0.47	0.47
F_{ABC}	0.45	0.45	0.47	0.47
OFL (t)	61,036	62,296	50,664	50,376
maxABC (t)	48,738	49,771	41,231	41,007
ABC (t)	48,738	49,771	41,231	41,007
Status	As determined in 2012 for:		As determined in 2013 for:	
	2011	2012	2012	2013
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Dusky rockfish

Changes in input data:

- 2013 trawl survey biomass
- 2012 fishery catch (and preliminary 2013)
- 2011 bottom trawl survey age composition
- 2011 fishery length composition

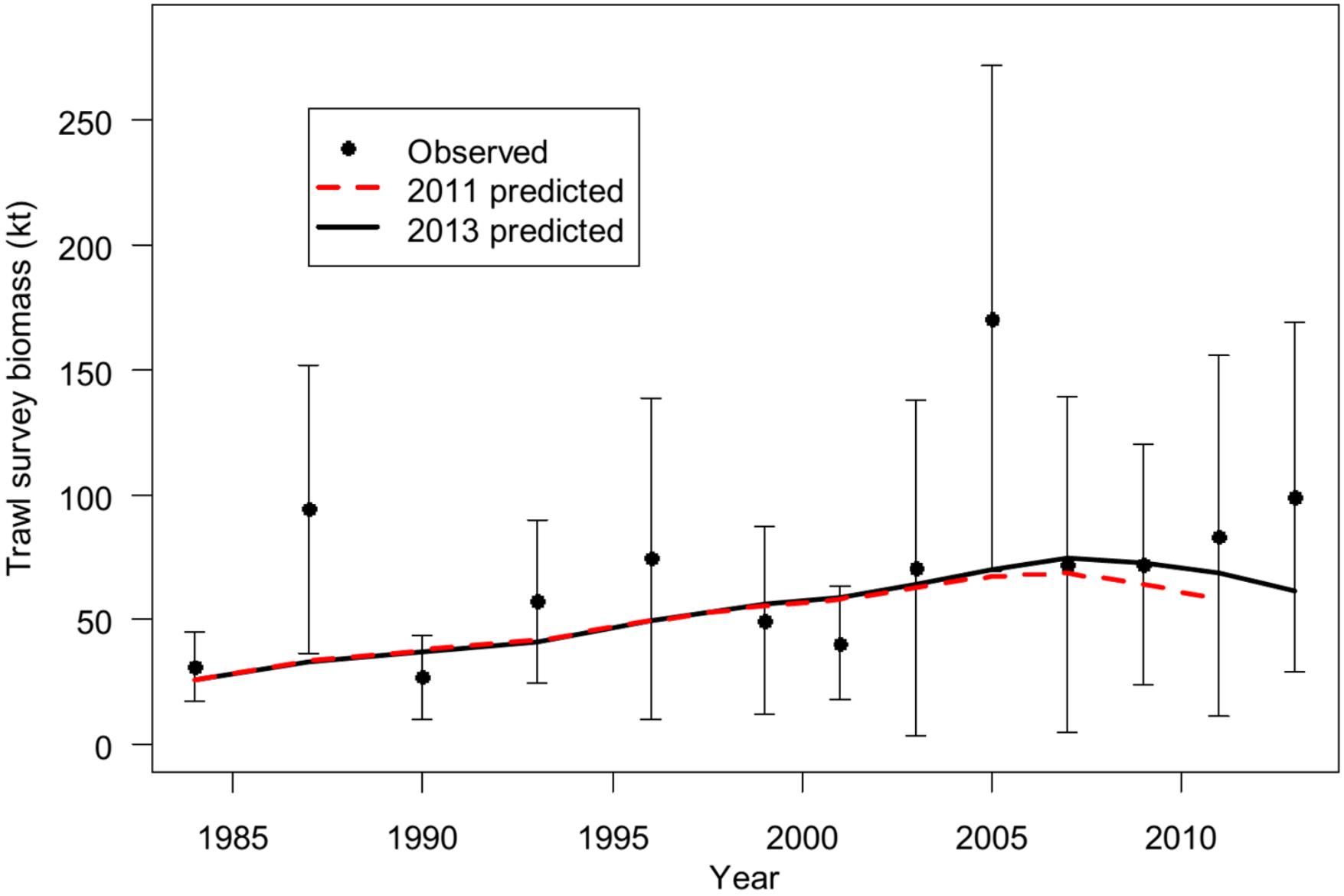
No changes in the assessment methodology

- 2011 model configuration with updated data

Dusky rockfish

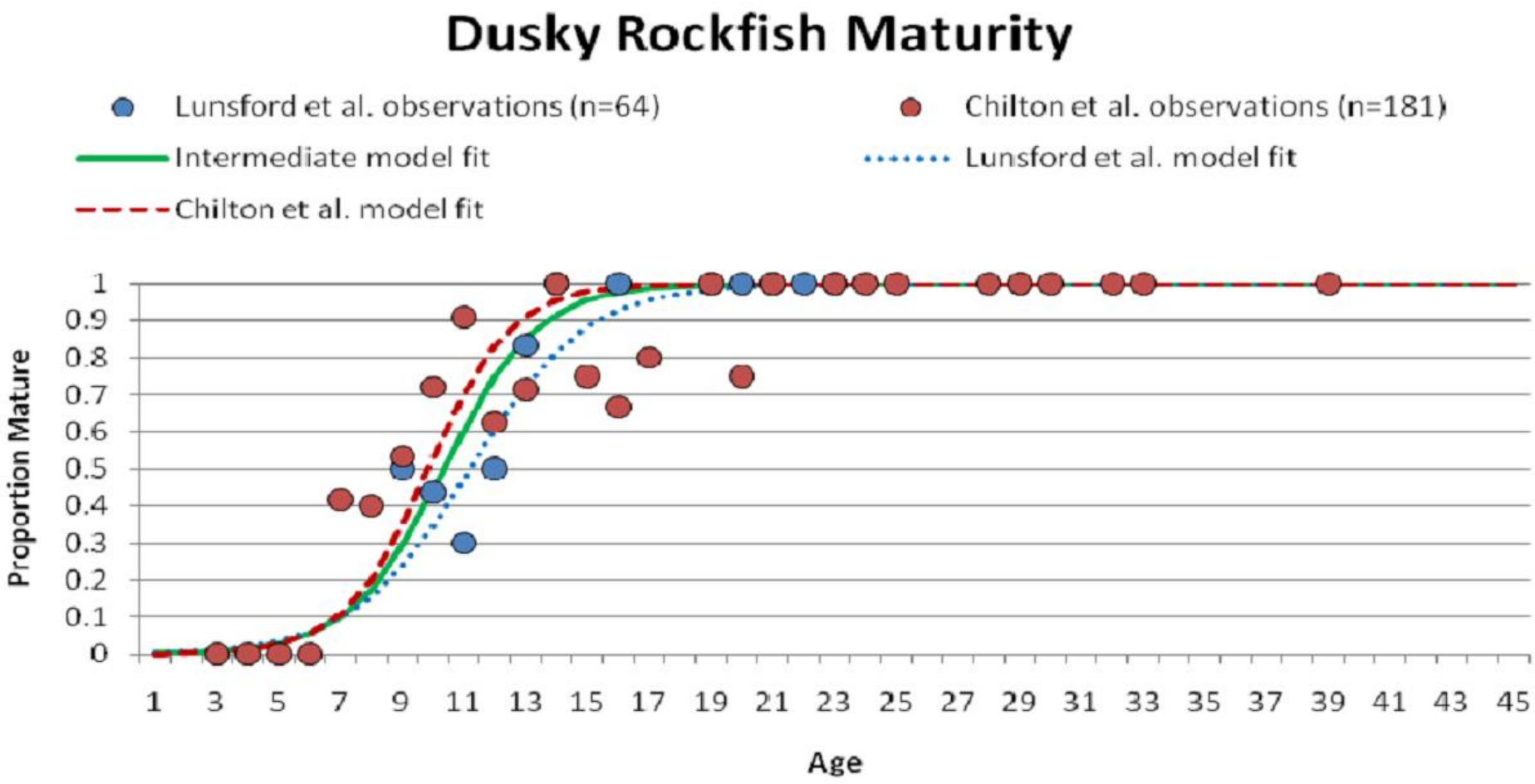
Source	Data	Years
Fisheries	Catch	1977-**2013**
NMFS bottom trawl surveys	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, 2011, **2013**
NMFS bottom trawl surveys	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, **2011**
U.S. trawl fisheries	Age	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2008, **2010**
U.S. trawl fisheries	Length	1990-1999, 2007, 2009, 2011

GOA Dusky rockfish



GOA Dusky rockfish

- Treatment of maturity studies/data



Eastern Bering Sea (EBS) pollock

Source	Type	Years
Fishery	Catch biomass	1964-2013
Fishery	Catch age composition	1964-2013
Fishery	Japanese trawl CPUE	1965-1976
EBS bottom trawl	Area-swept abundance (numbers) index	1982-2013
EBS bottom trawl	Proportions at age	1982-2013
Acoustic trawl survey	Population abundance (numbers) index	1979, 1982, 1985, 1988, 1991, 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012
Acoustic trawl survey	Proportions at age	1979, 1982, 1985, 1988, 1991, 1994, 1996, 1997, 1999, 2000, 2002, 2004, 2006-2010, 2012
Acoustic vessels of opportunity (AVO)	Population abundance (numbers) index	2006-2013

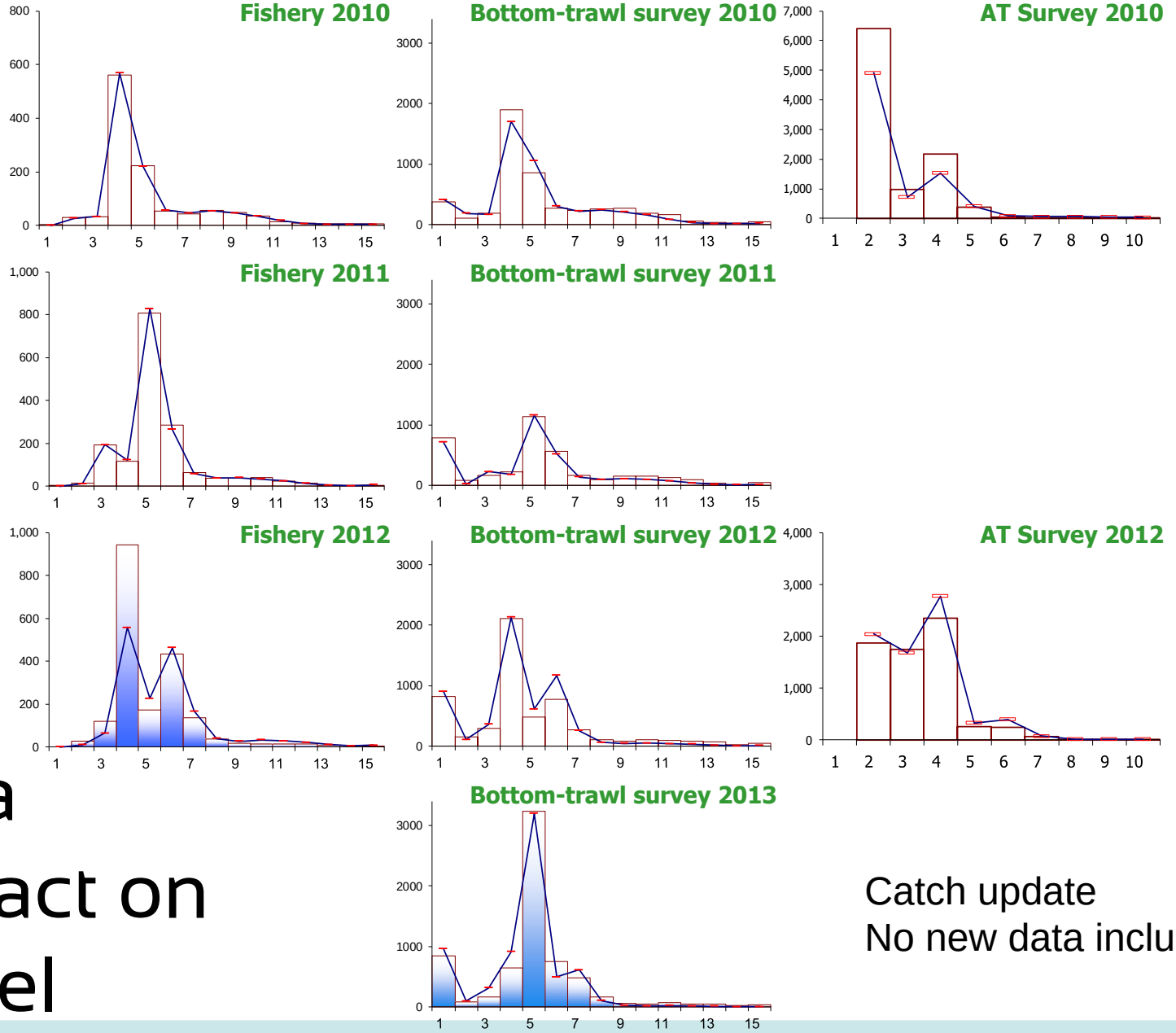
Models

Data Impact on Model

Data considerations					
Name	**Updated catch to 2013**	**2012 Catch age**	**2012 AT Age data**	**2013 Bottom trawl**	**AVO 2012 and 2013**
Mod0.0	X				
Mod0.1	X	X			
Mod0.2	X	X	X		
Mod0.3	X	X	X	X	
Mod0.4	X	X	X	X	X

Kotwicki index: efficiency correction for bottom trawl survey data	
Mod2.0	Uses multivariate lognormal (over time) instead of univariate

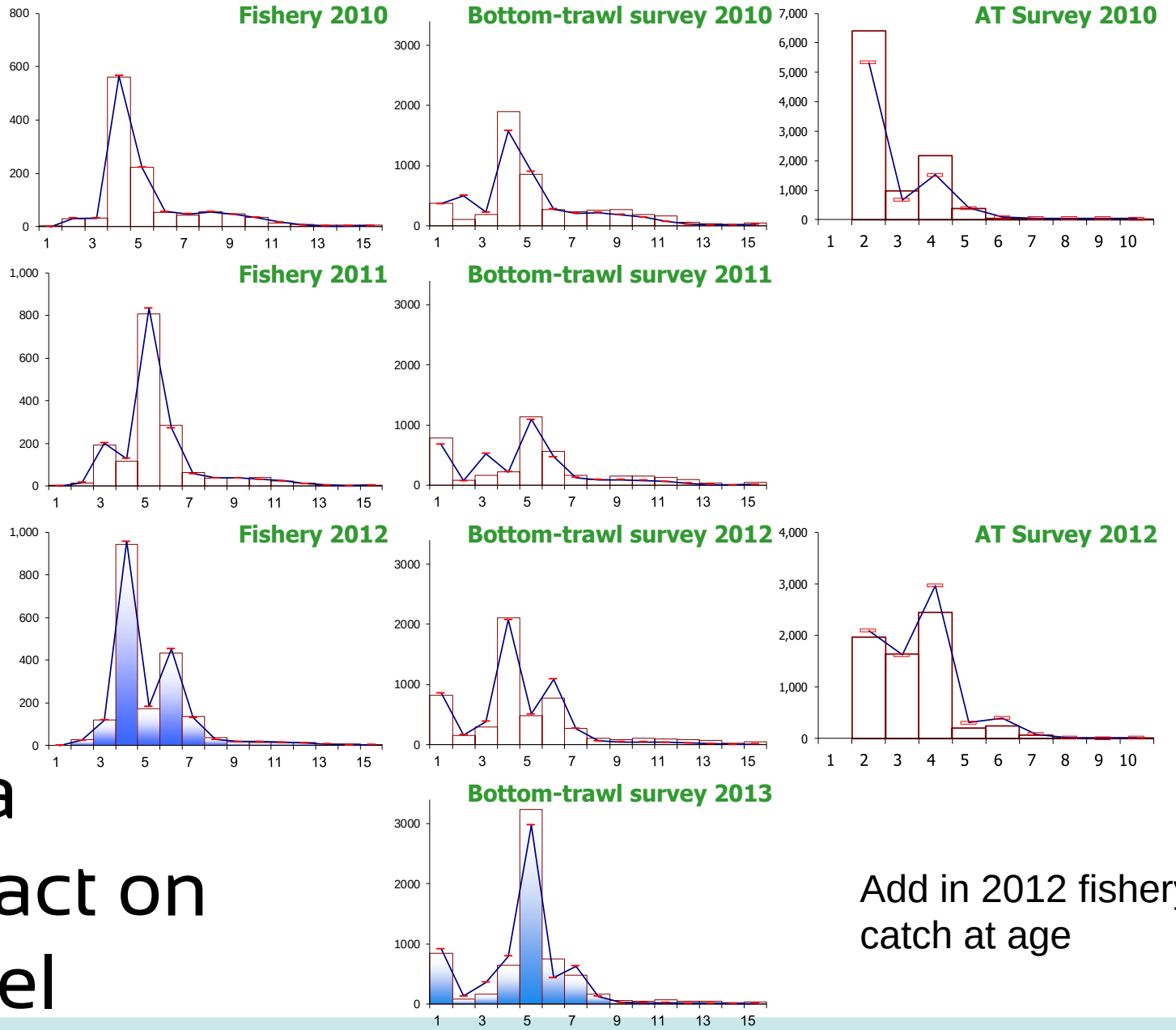
model0_0



Data Impact on Model

Catch update
No new data included

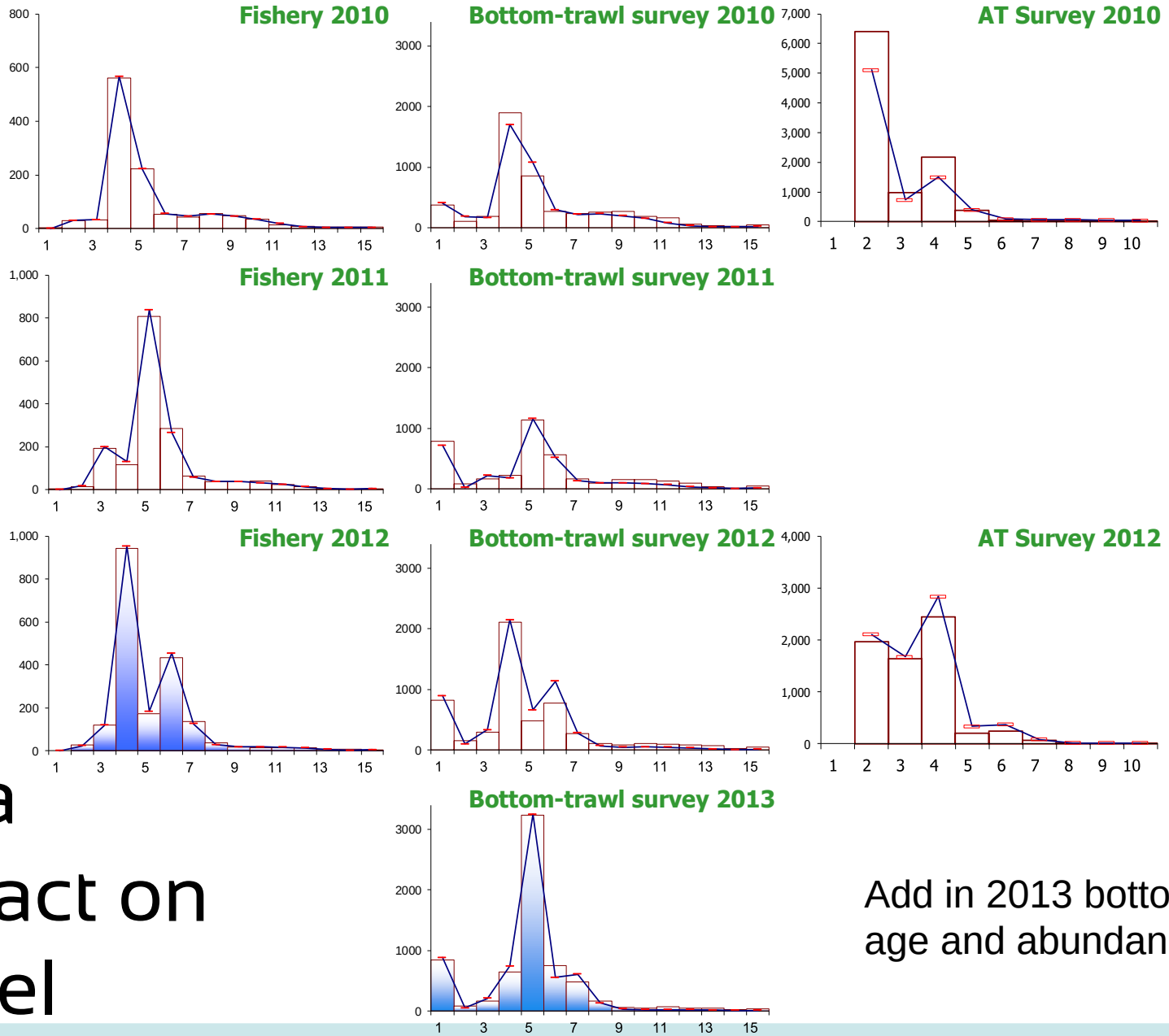
model_0_2



Data Impact on Model

Add in 2012 fishery catch at age

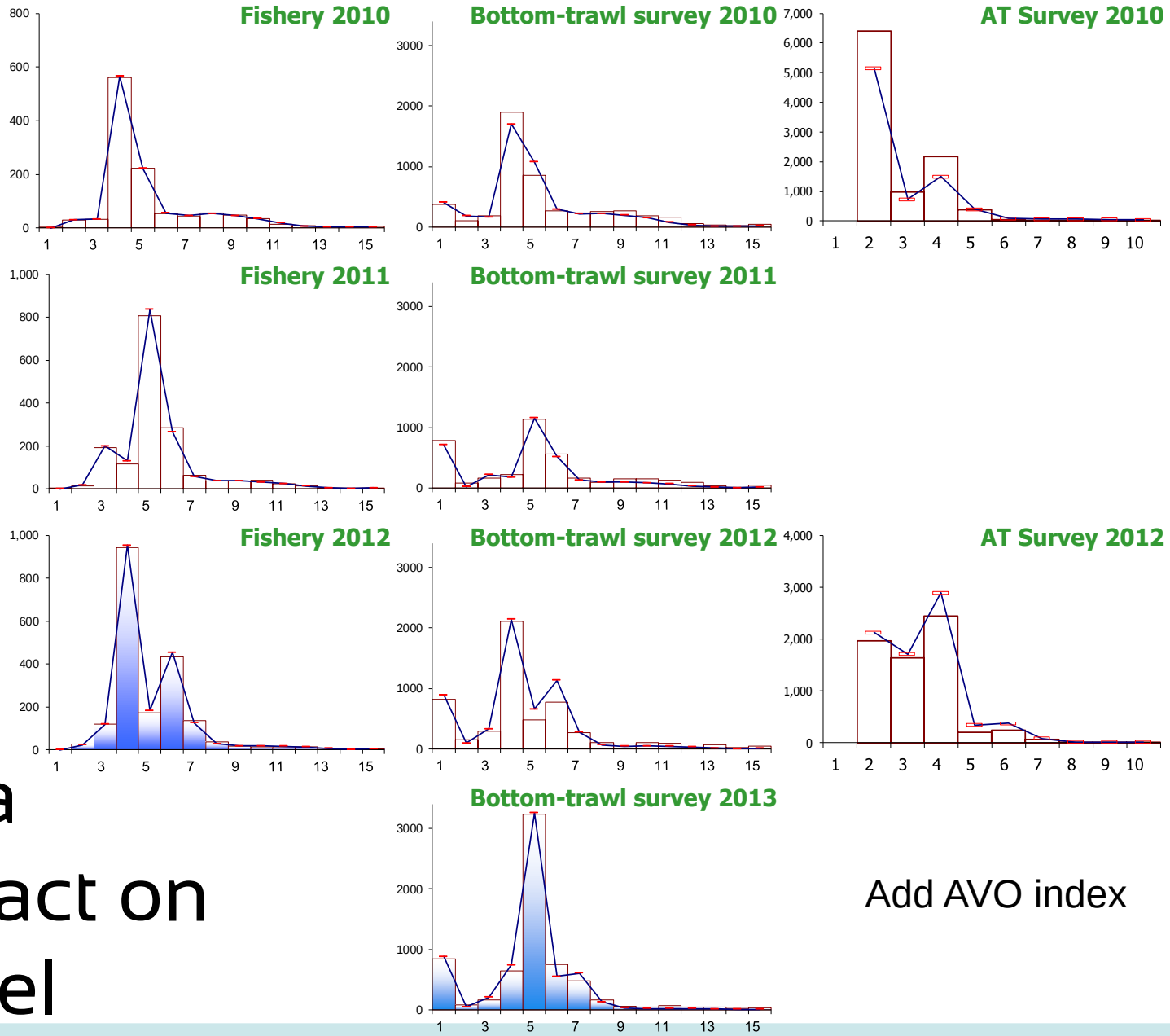
model_0_3



Data Impact on Model

Add in 2013 bottom trawl age and abundance data

model_0_4



Data Impact on Model

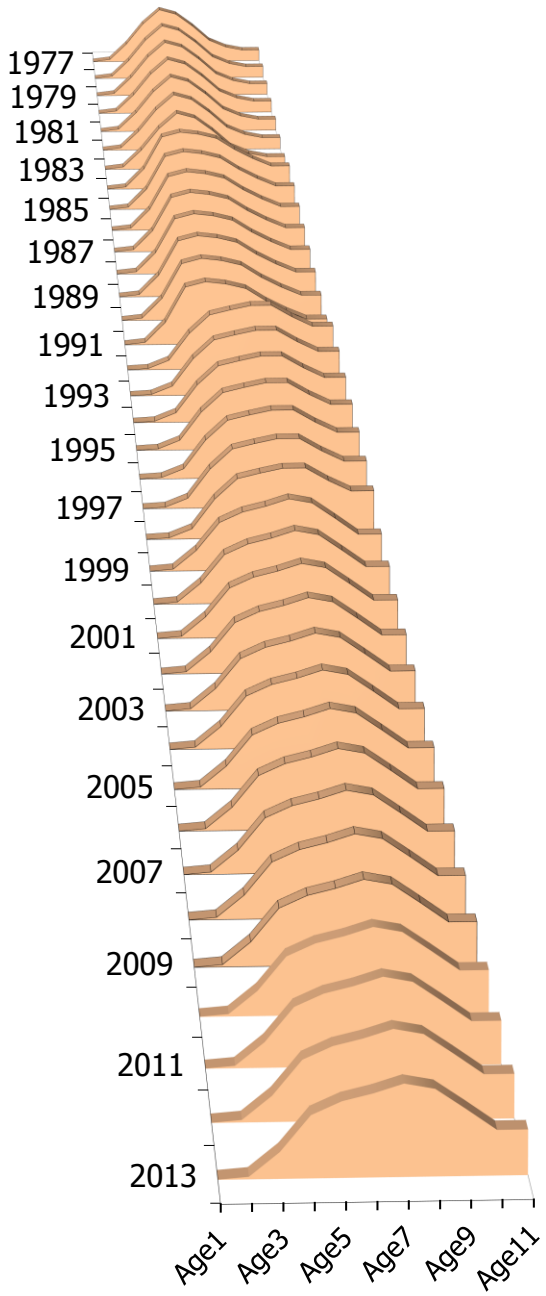
Add AVO index

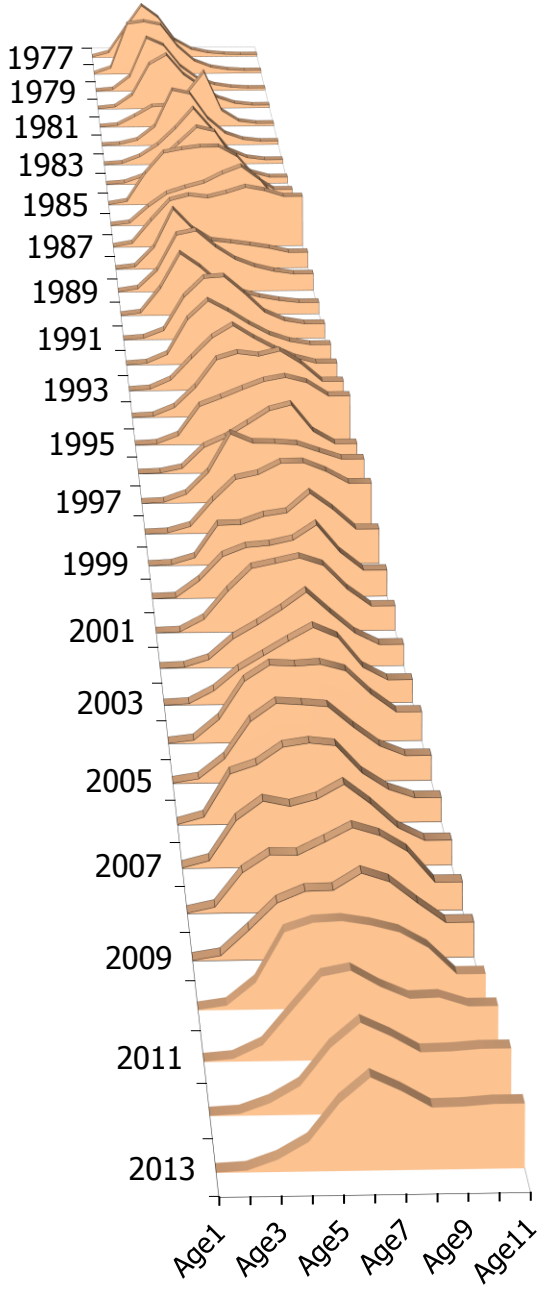
BSAI Atka mackerel

Data component	Years of data	Distribution
Catch biomass	1977-2013	Lognormal
Fishery catch age composition	1977-2012	Multinomial
Survey biomass	1991, 1994, 1997, 2000 2002, 2004, 2006, 2010, 2012	Lognormal
Survey age composition	1986, 1991, 1994, 1997, 2000 2002, 2004, 2006, 2010, 2012	Multinomial
Prior penalties	Recruitment deviations	Lognormal
	Stock recruitment curve	Lognormal
	Selectivity smoothness (in age-coefficients, survey and fishery)	Lognormal
	Selectivity change over time (fishery and survey)	Lognormal
	Priors (where applicable)	Lognormal

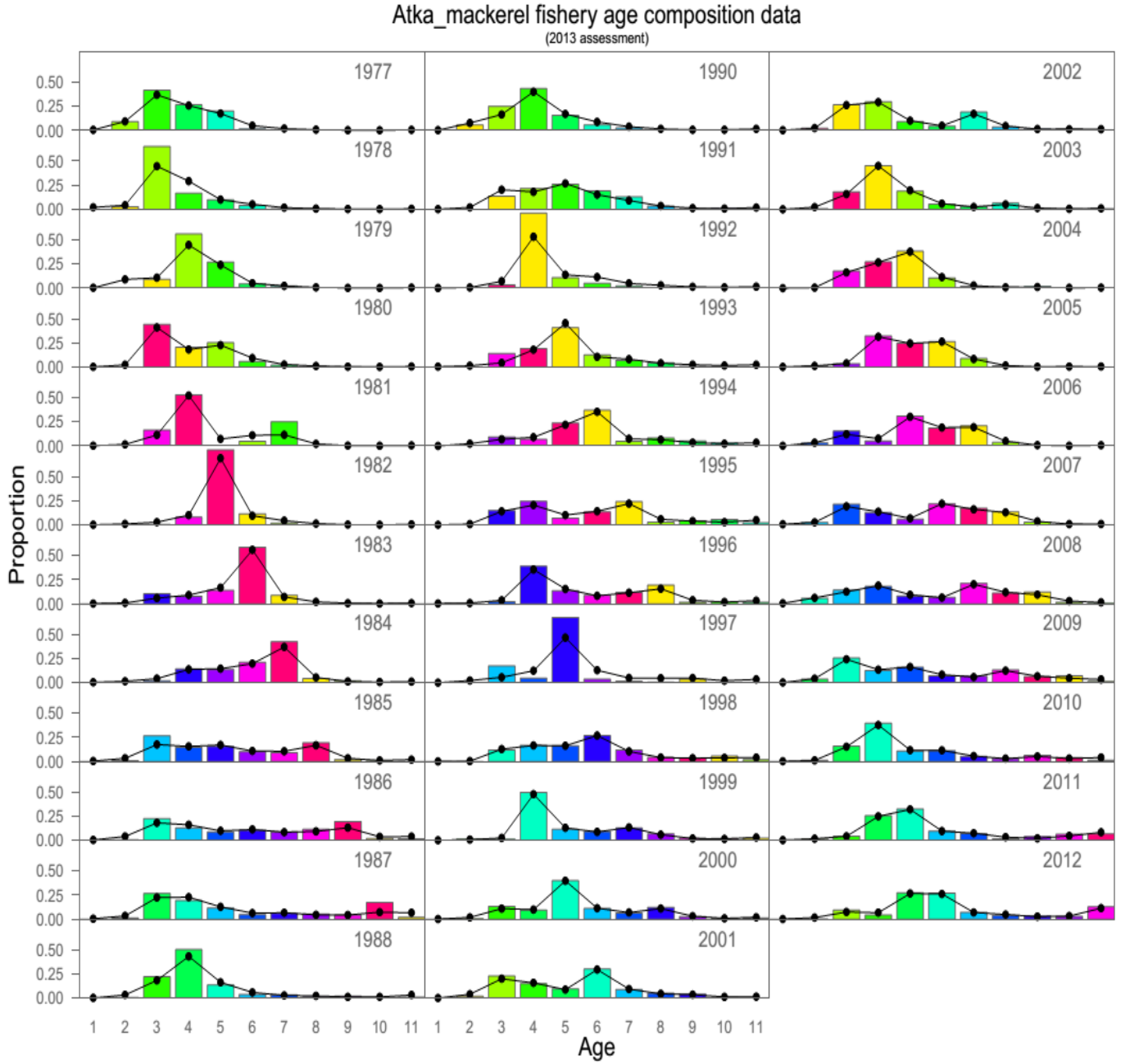
Selectivity

Example presentation of model configurations





Example presentation of model fit

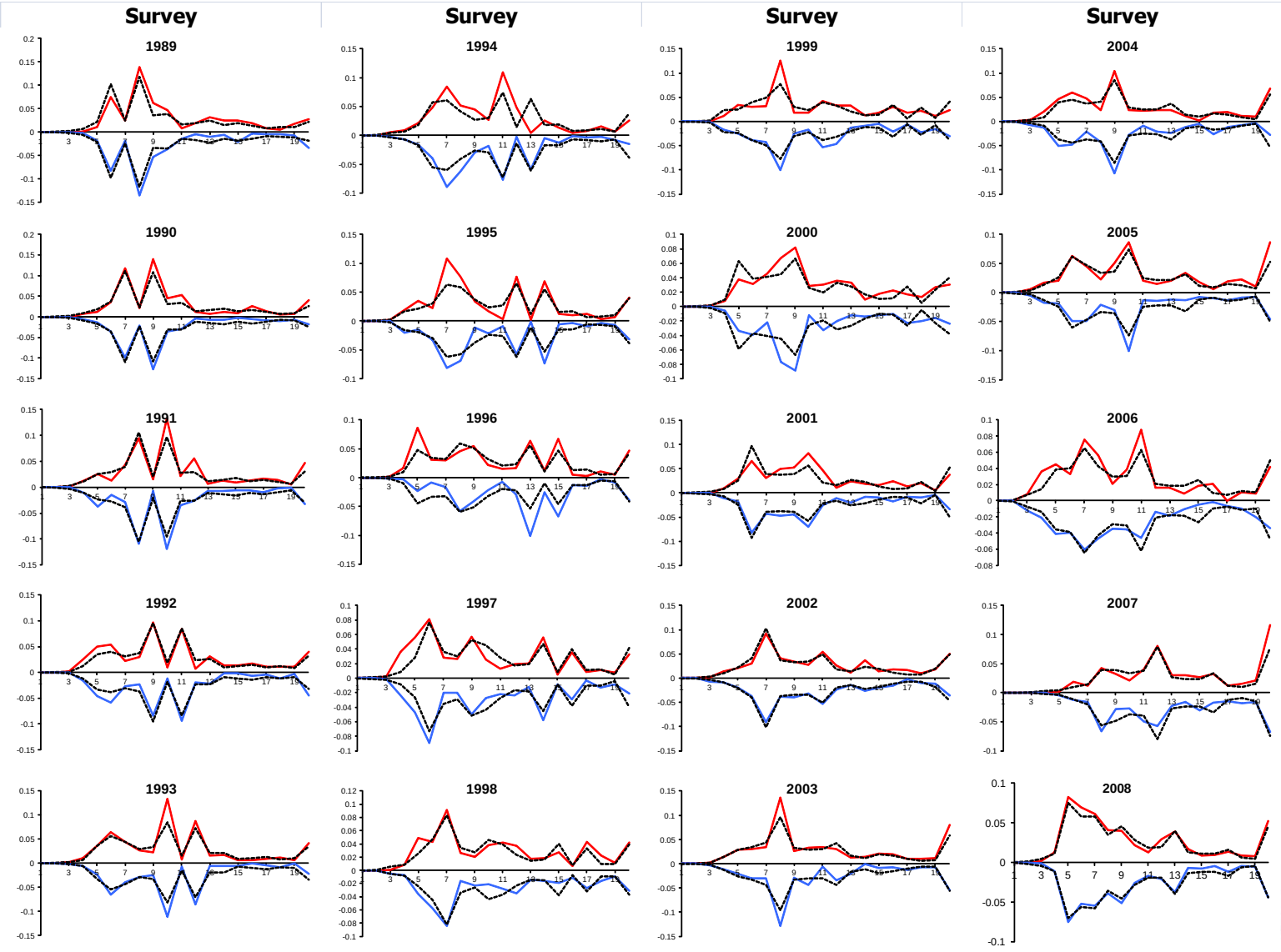


BSAI Yellowfin sole

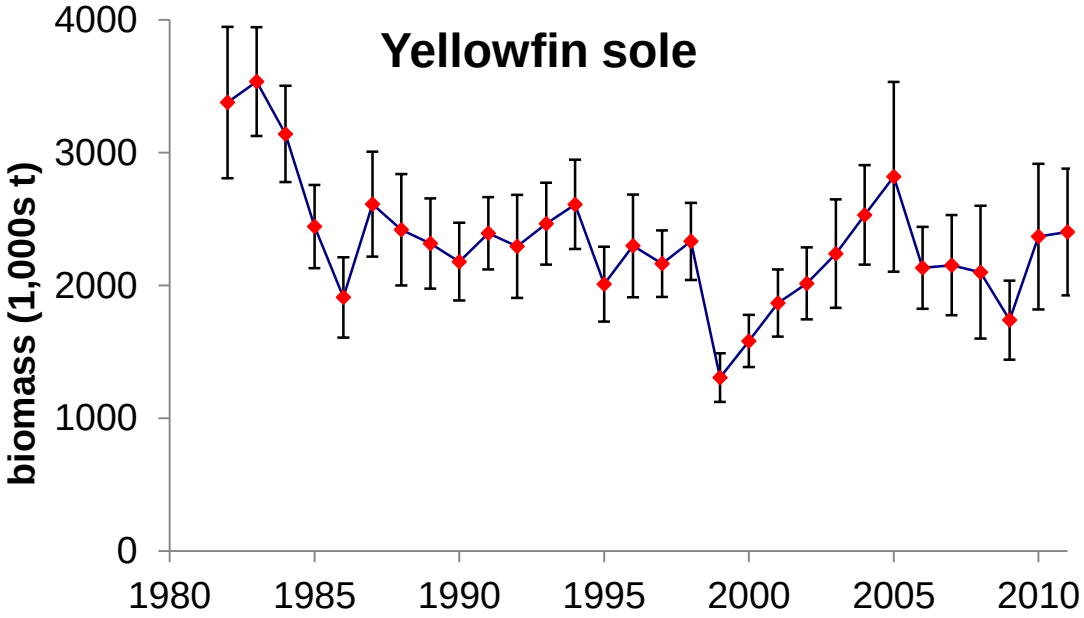
…the largest (by volume) flatfish fishery in the world

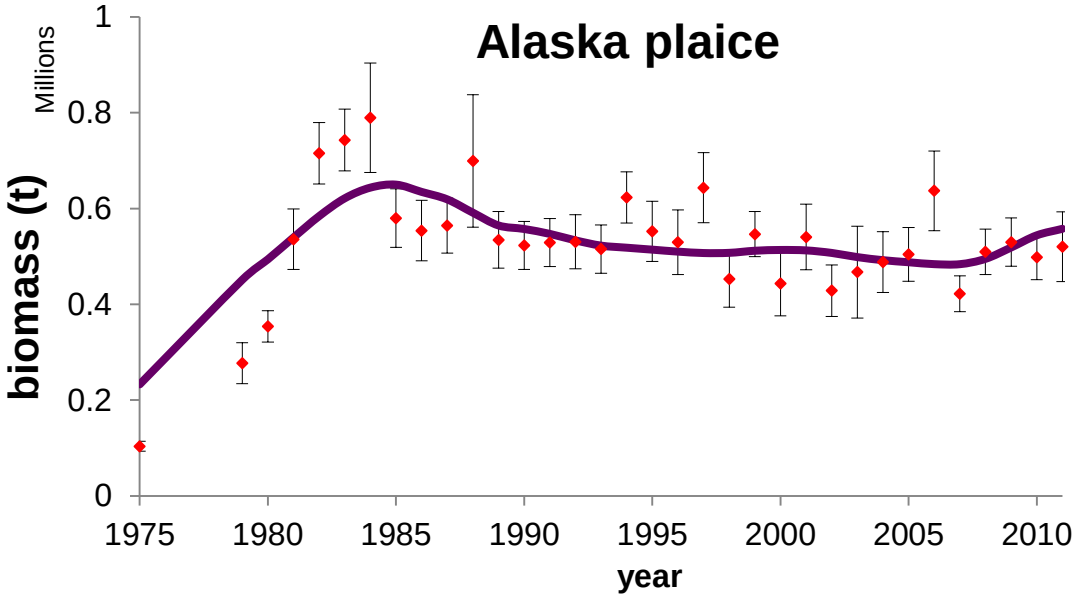
Data source	years
Fishery catch	1954-2013
Fishery age composition	1964-2012
Survey biomass and standard error, bottom temperature	1982-2013
Survey age composition	1979-2012
Annual length-at-age and weight-at-age	1979-2012
Maturity at age	Samples collected in 1992 and 1993

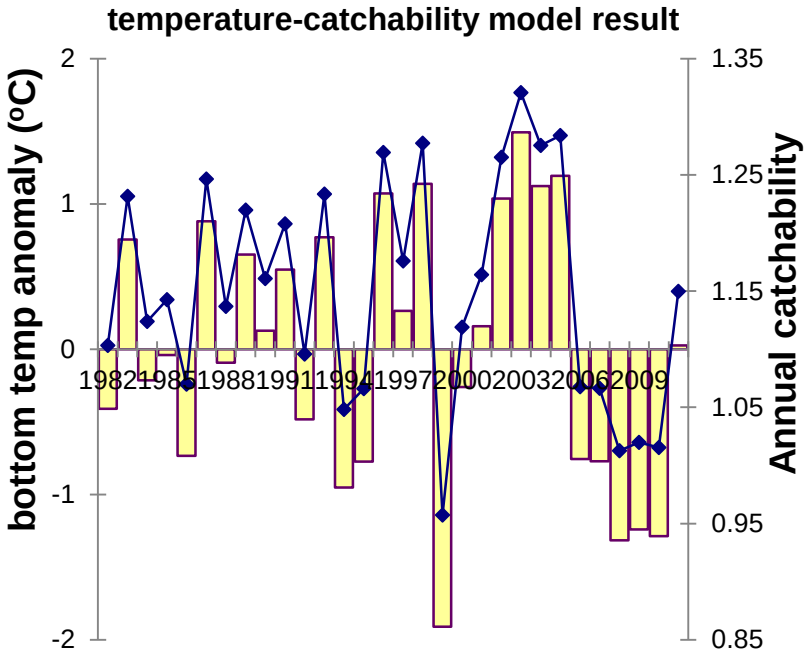
Yellowfin sole data fit presentations



Flatfish behavior and survey estimates







$$q = e^{\alpha + \beta T}$$

Projection model

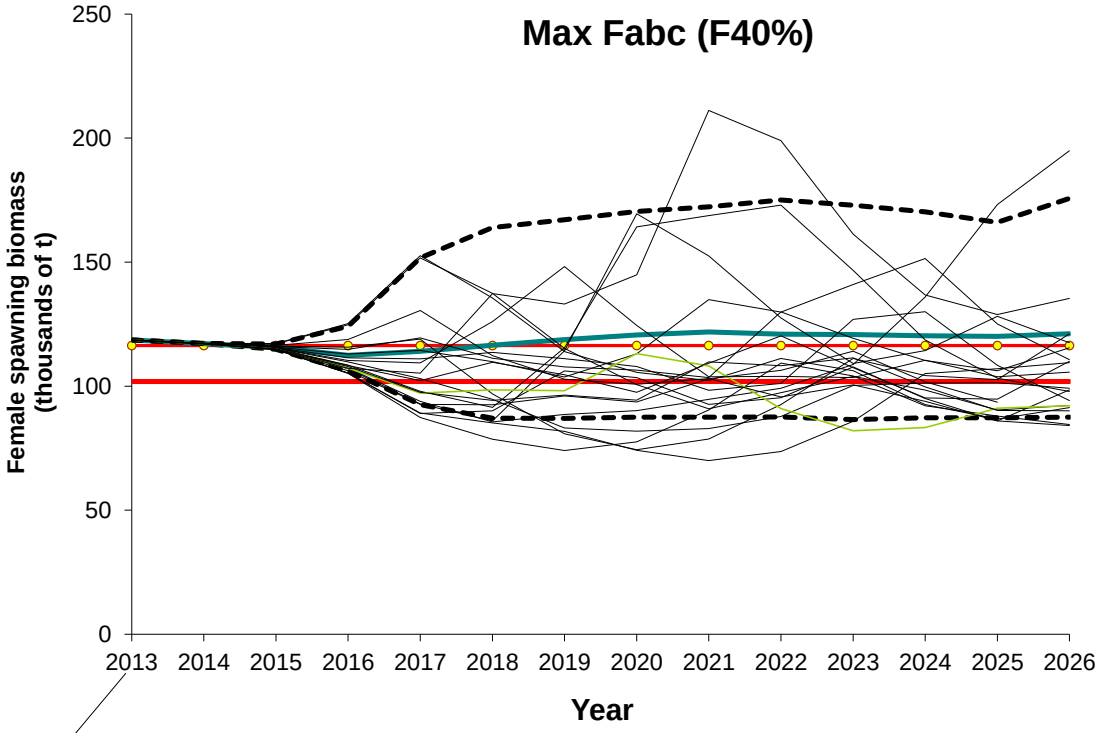
Standard projection

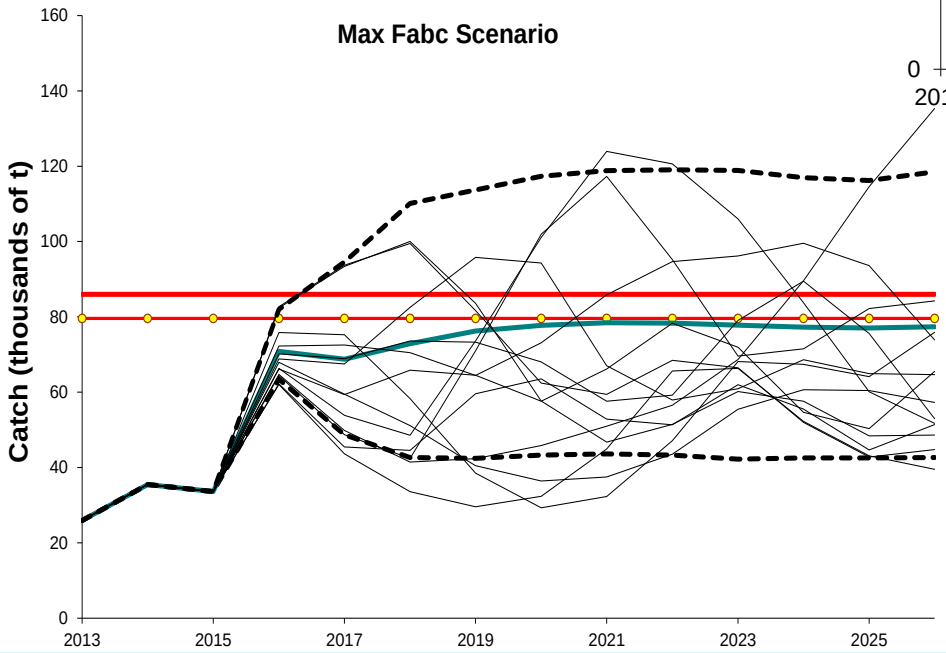
- Inputs:
  - Numbers at age at current year (begin-year)
  - Current year best-estimate of catch
  - Selectivity, natural mortality, maturity/fecundity
- Simulates recruitments to have same mean and variance as observed from 1977- present
- Future fishing rates
  - 7 different control-rules

Projection model

Example results

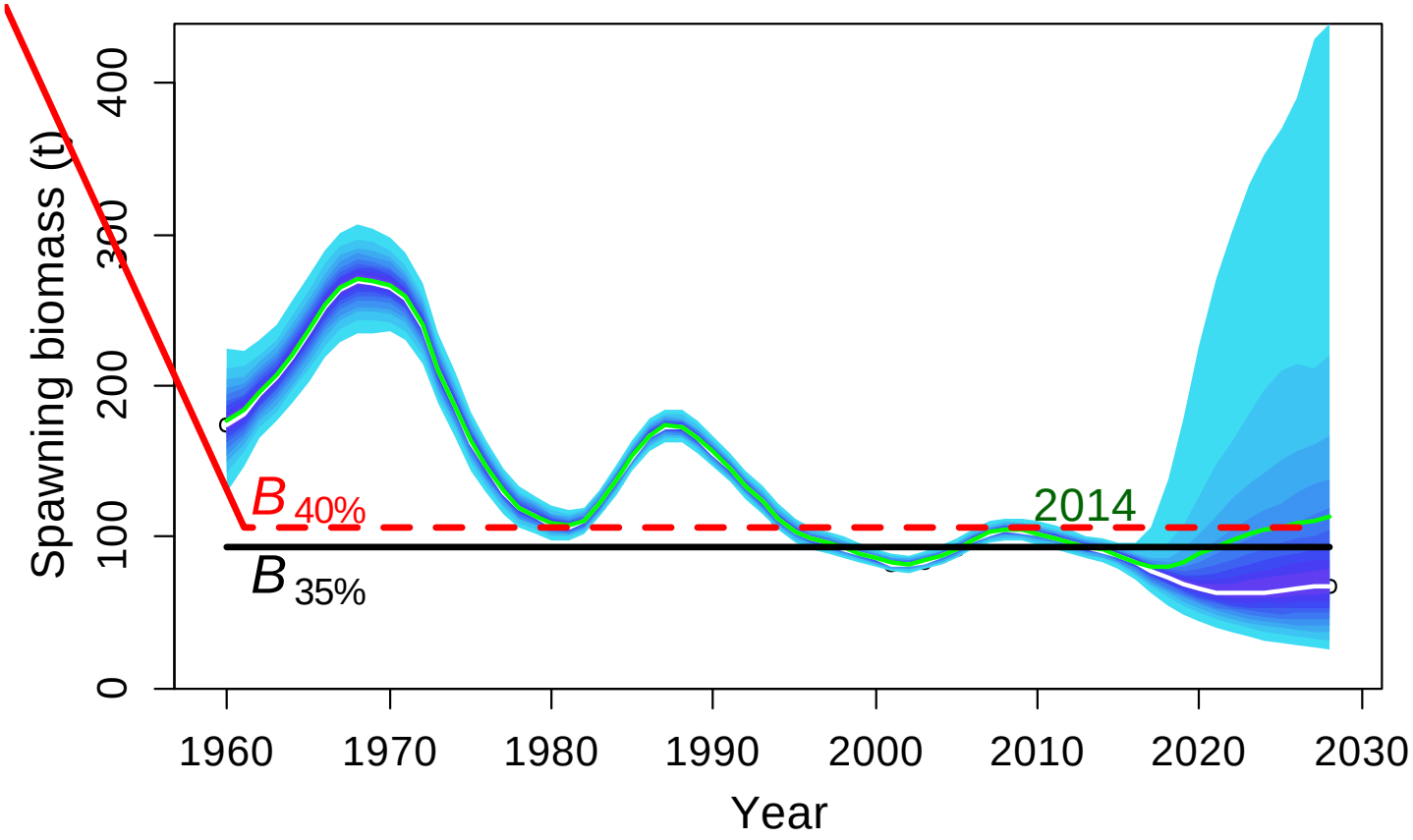
One scenario





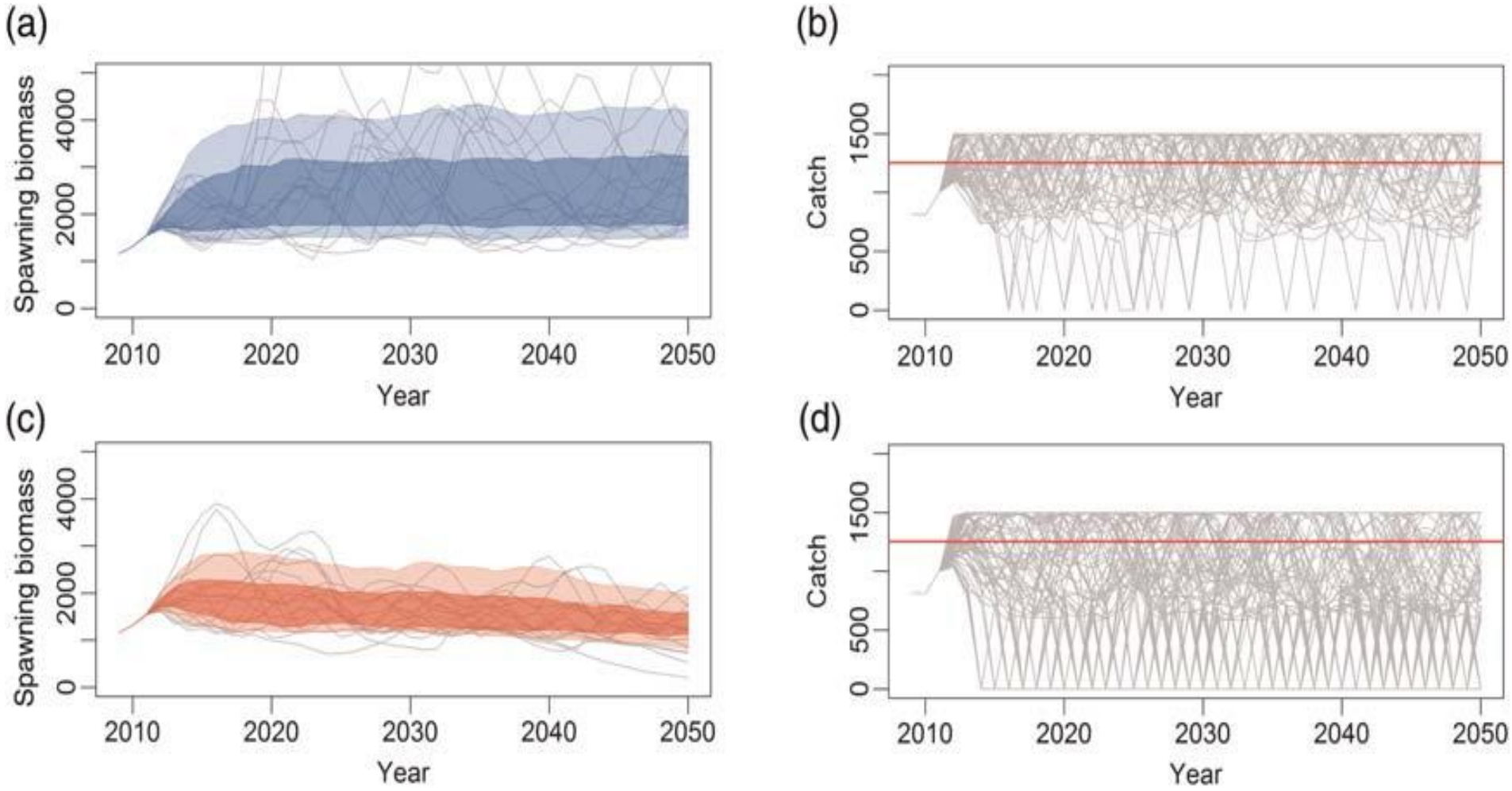
Projection model application

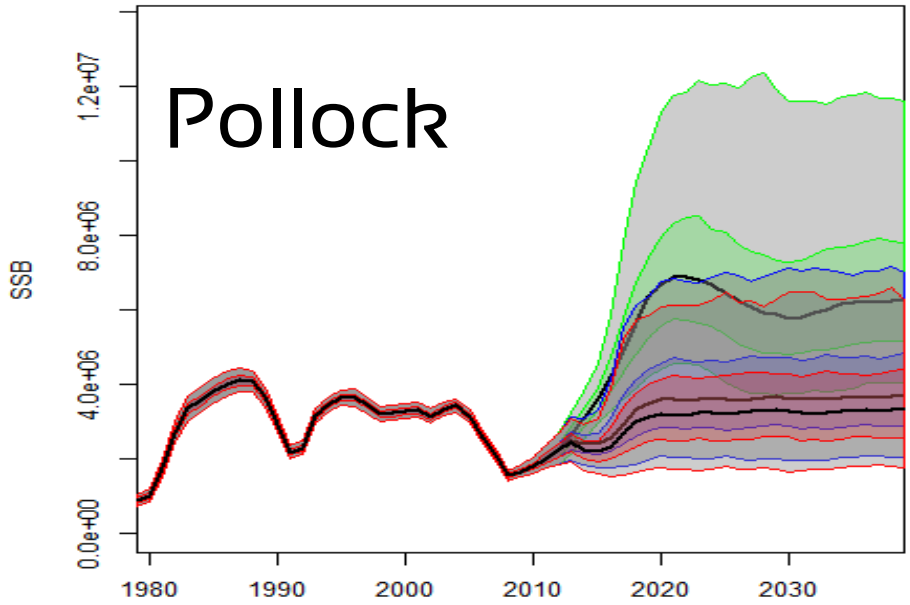
- Propagated within model
  - Uncertainty carries into future

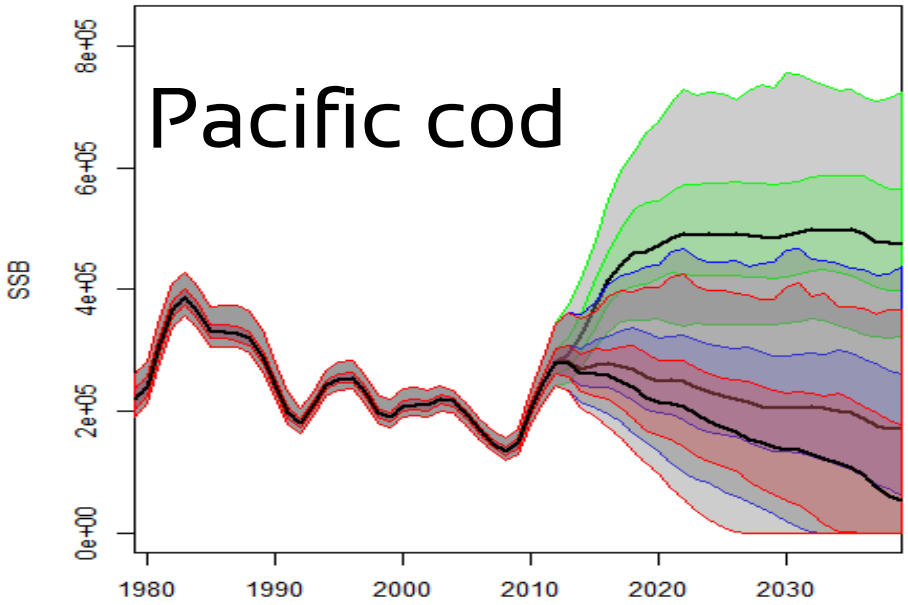


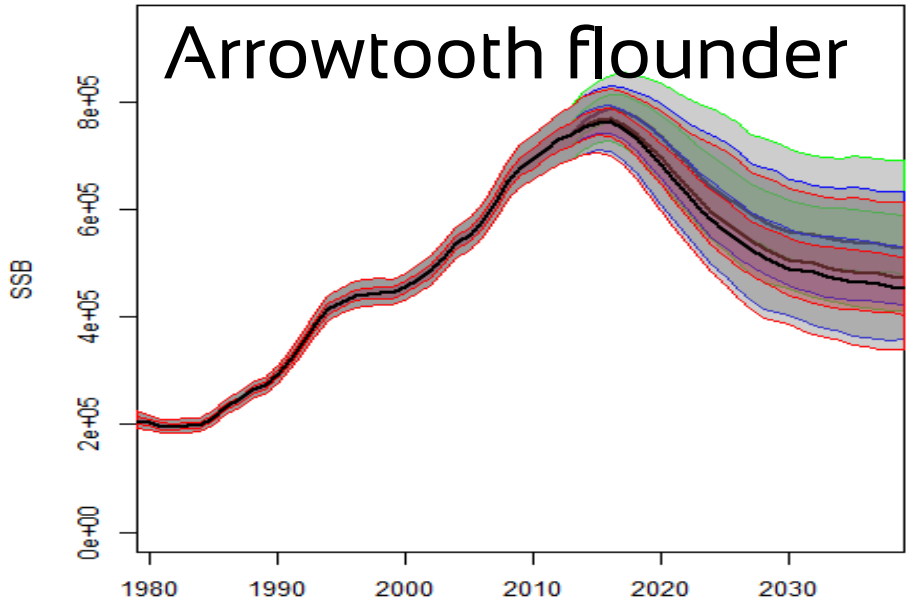
Projection model

EBS pollock under climate change









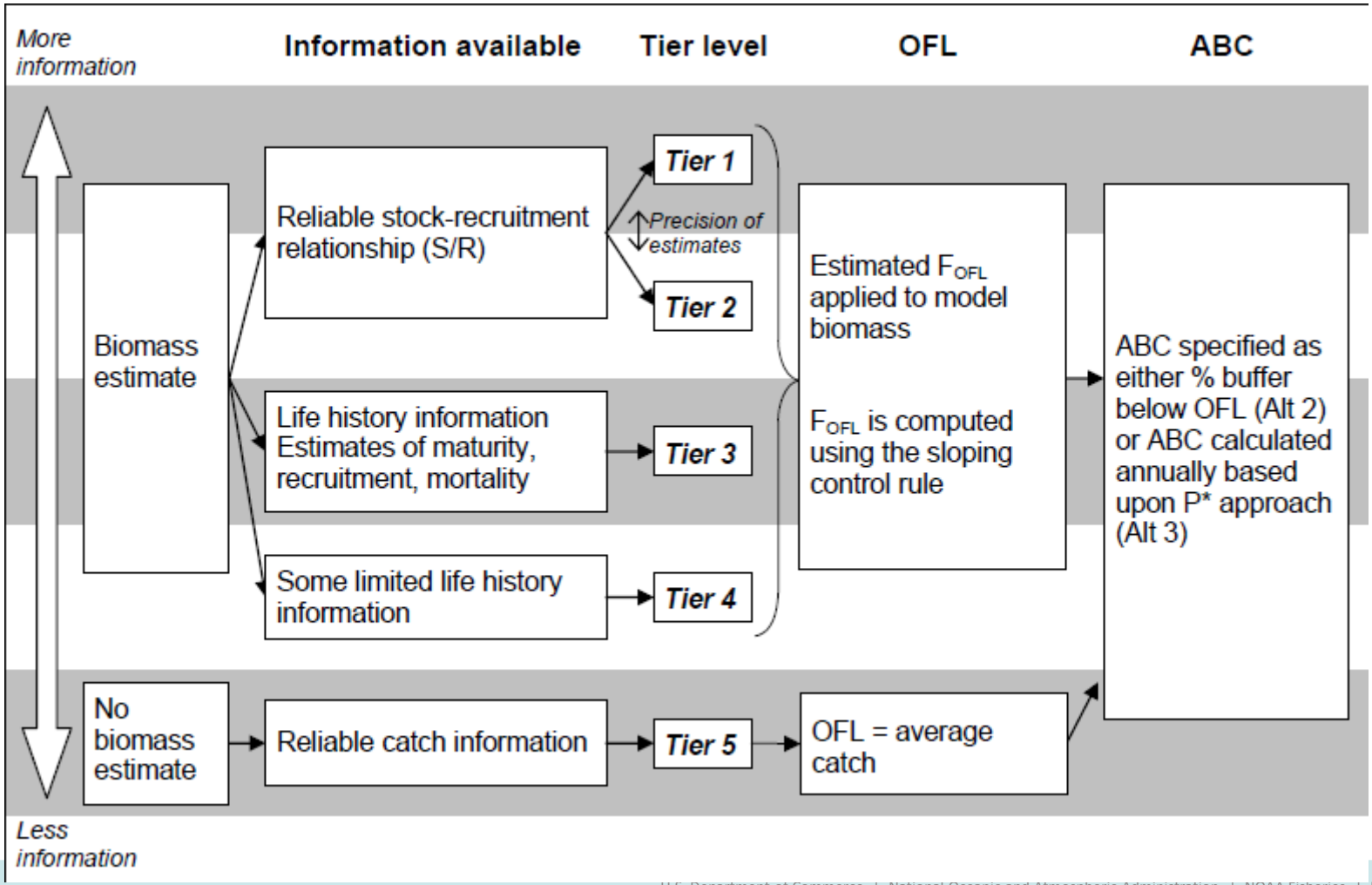
Projections for multi-species models

Ecosystem modeling relative to assessments

- Pollock – Pacific cod – Arrowtooth EBS MSMt model
  - Multi-species trophic interaction model with temperature
  - Modified to do MSE testing and evaluation (extension of BSIERP)
- Spatial pollock model and climate change
  - Simulation testing impacts
    - Hulson et al. 2013; Hulson et al. 2014
- **Sablefish** recruitment
  - Environmental index within the assessment model
    - Shotwell et al. 2013
  - For later-recruiting species to improve near-medium term projections
  - Historical recruitment estimates can be improved where demographic data not available

Hulson, P. F., Ii, T. J. Q., Hanselman, D. H., & Ianelli, J. N. (2013). Spatial modeling of Bering Sea walleye pollock with integrated age-structured assessment models in a changing environment, *15* (July), 1–15.

Crab tier system



Assessment Responsibility

- NMFS responsibility
  - Snow
  - Tanner
  - Pribilof Islands Red King Crab
  - Pribilof Islands Blue King Crab
- State responsibility
  - Approximately 5 stocks (Blue King Crab, Red King Crab, Golden King Crab)

Size-based crab models

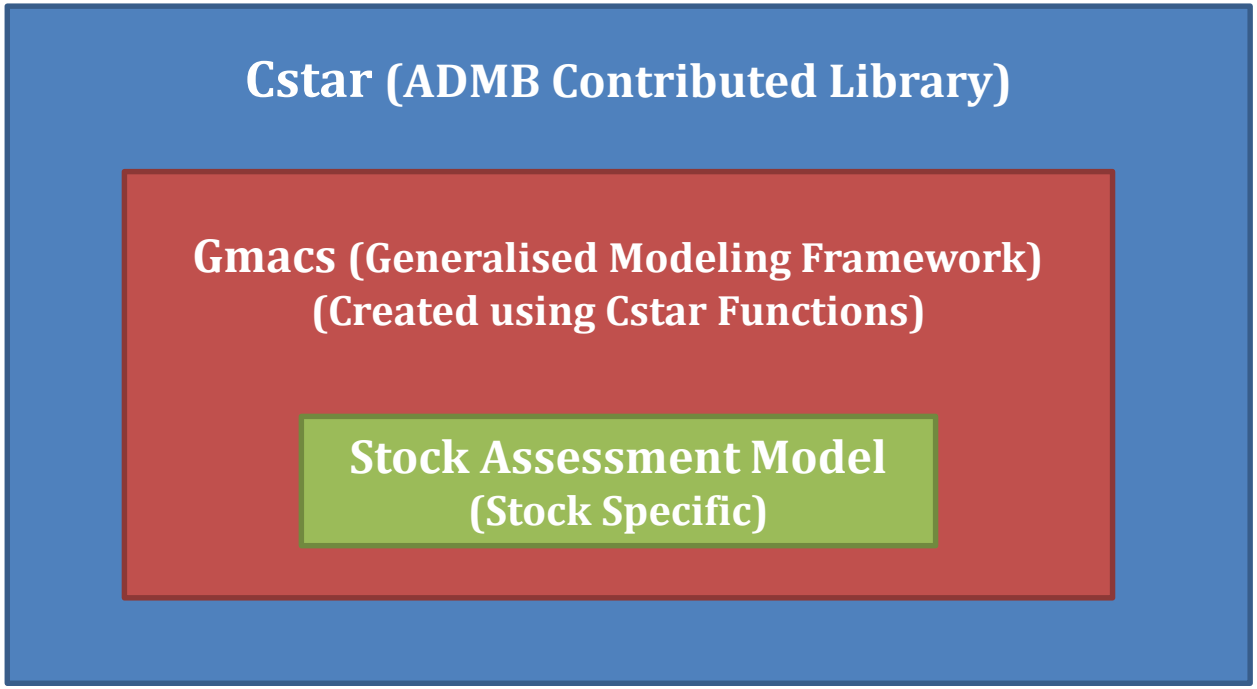
- Similar in philosophy, i.e., Integrated statistical assessment modeling (for "data-rich" stocks)
- Size-based dynamics
  - Sex structured Differential growth and exploitation
  - Discrete time-step dynamics
    - Within a season , temporal fishery pattern, molting, and survey
  - Annual size-transition matrix
  - Most models include molting and maturation probabilities
    - Including terminal molt to maturity

Size-based crab models

- Composition data more complex than typically used for groundfish
  - Size, sex, shell condition, maturity status

Generalized Modeling for Alaskan Crab Stocks (Gmacs)

- Common Stock Assessment Routines (Cstar)



… can be used to make generalised modeling packages, and thus specific stock assessment models

Publicly available

UBLIC awhitten / **gmacs**

Unwatch 3 | Unstar 2 | Fork 1

Generalized modeling for Alaskan crab stocks: a generic size-based stock assessment model

133 commits | **2** branches | **0** releases | **2** contributors

branch: **master** | **gmacs** /

Update README file

awhitten authored 21 days ago — latest commit 9630179a62

examples	Remove XLS file	2 months ago
scripts	Update gmacs.r and add new source file	2 months ago
src	Fix naming conventions and syntax for temporary functions	21 days ago
README.md	Update README file	21 days ago
ignore.gitignore	Update gitignore file	3 months ago

README.md

Gmacs Version 1.0

This is the pilot release of Gmacs. Currently posted source files are compilable using ADMB 11.1 and have been tested using the BBRKC model available in the examples folder. This release will remain active until the current 'under development' version is released. **Updated February 2014, by Athol Whitten**

Generalized Modeling for Alaskan Crab Stocks

Code

Issues 1

Pull Requests 0

Wiki

Pulse

Graphs

Network

HTTPS clone URL

https://github.com/

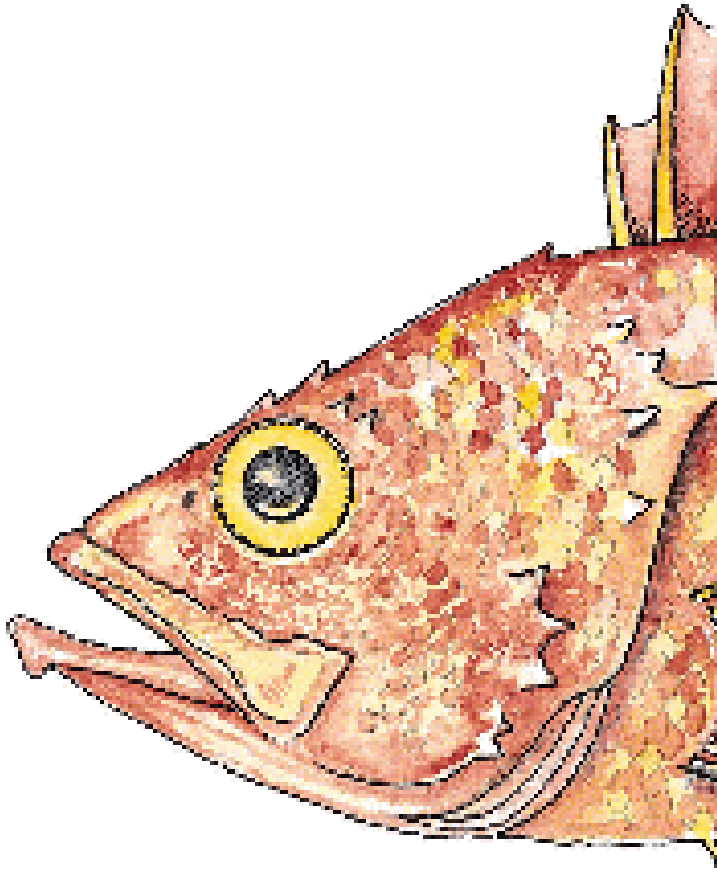
You can clone with HTTPS, SSH, or Subversion.

Clone in Desktop

Download ZIP

Assessments for Tier 5 stocks
(Less rich data-wise)

- Working group on survey averaging



Working group

Survey averaging methods inconsistent:

- Weighted
- Unweighted
- The most recent estimate
- Kalman Filter

- Also, stock-wide abundance sometimes different than biomass by subarea.

Tasks: evaluate methods

- To produce a "reliable" estimate of biomass for stocks/complexes managed under Tier 5
- Also
  - To use survey for apportionment
  - To "fill-in" gap areas for years when funding was unavailable for a complete survey

Simulation testing approach

Survey CV:

lognormal distribution, 0.15 and 0.35

Natural mortality (*M*):

0.06 and 0.30

Recruitment variability (σ_R):

0.8 and 0.4

Survey frequency:

Annual, biennial, and triennial

Trend in fishing rate/biomass:

1) increasing, then decreasing
2) decreasing, then increasing
3) constant

Three estimation methods

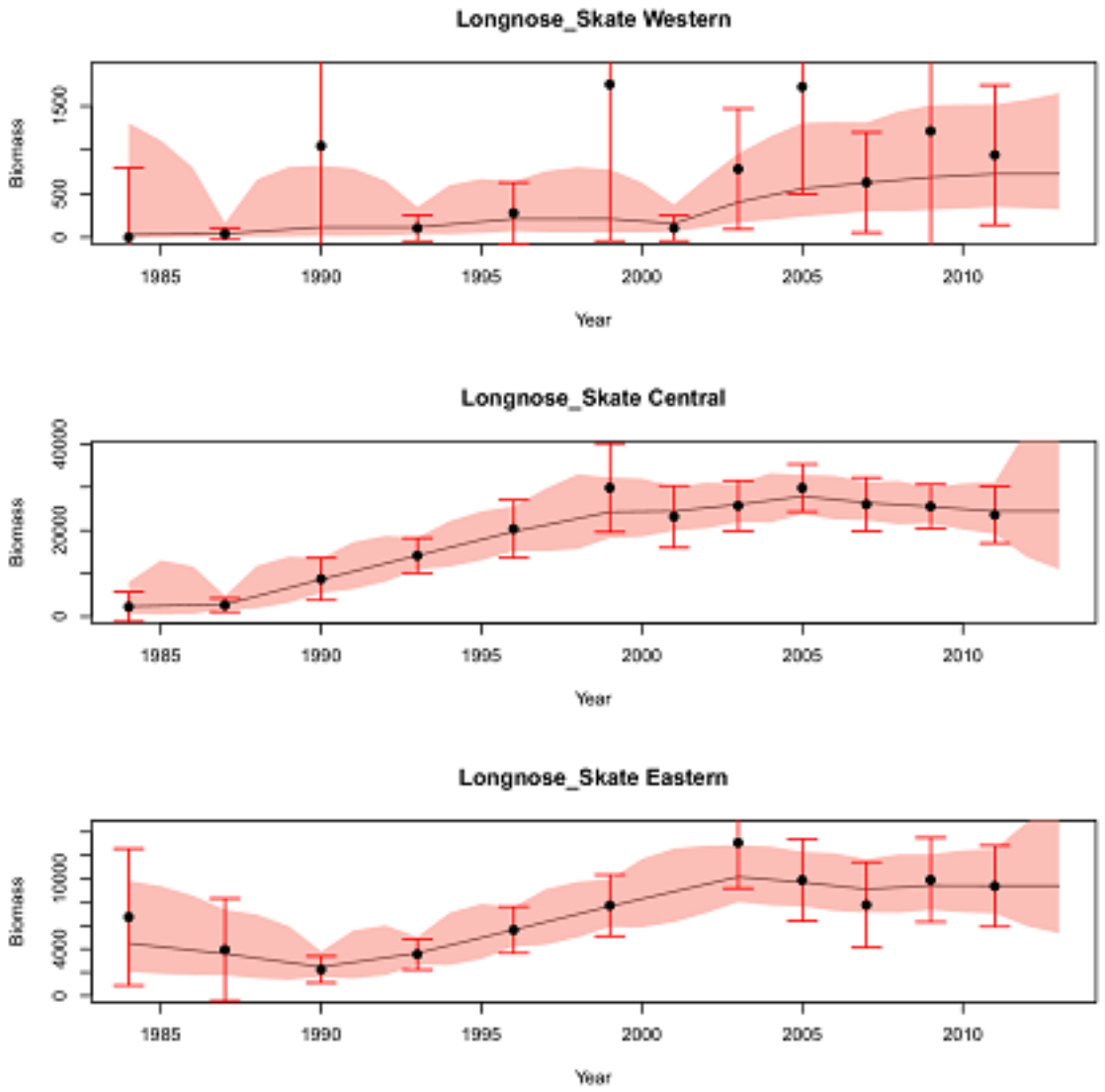
1) Exponential smoothing
2) Random effects model
3) Generalized ARIMA modeling

Plan Team and SSC
Recommendations

- Random effects model
  - Advantages
    - Simple to apply
    - Flexible (i.e., can use alternative error structures)
    - Performed well in simulations
    - Will also likely be useful for area apportionments
  - Disadvantages
    - Other methods had better performance in some cases
    - More complex than current methods

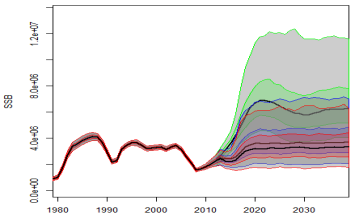
Survey average

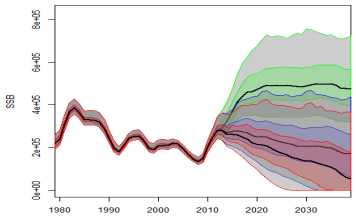
Survey averaging approaches With missing areas

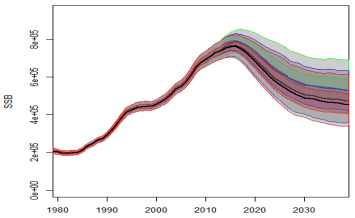


Strengths

- Data-rich system
  - Age-structured modeling for most key stocks
- Regular updates
  - Reviews allow for evolutionary model development
  - Fewer surprises and disruptive shifts
- Use of multiple software platforms
  - Innovation and development of stock-specific custom models
  - Allows testing of common packages







Challenges

- Annual assessments limit research
- Data-limited approaches need further work
  - Improvements in biomass estimates
  - Improvements in Fmsy proxies
- Annual catch limits successful, but:
  - Link to scientific uncertainty can be improved
- Ecosystem research
  - Trade-offs with fundamental assessment/survey work
  - Better linkages between ecosystem research and catch advice
  - Better accounting of uncertainty

Possible Solutions

- Account for process errors more fully
  - Support state-of-the-art software
- Develop/apply survey CPUE models
  - Stock-specific catchability and absolute biomass
- Refine estimates of total catch
  - Especially non-target species
- More comprehensive treatment of data
  - E.g., environmental conditions for recruitment estimation and catchability
- Revise control rules
  - Explicit consideration of buffers for groundfish

Theme I Summary
Scientific/technical approach to fishery stock assessment modeling

a) Is the Center using an appropriate suite of analytical methods to meet the regional fishery stock assessment objectives?

b) Does the suite of assessment models cover considerations from data-poor to data-rich?

c) Are assessments capable of considering possible ecosystem effects?

d) Does the Center work on enhancing and testing these analytical methods? Are they keeping with and contributing to the state-of-the-science nationally and internationally?

Relative to national and international contributions

- Assessment scientists wear many hats
  - Various working groups (regional and national)
  - Advisory panels
  - ICES contributions
  - Publications

- See lists of activities and other presentations for more info